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The Kent Incorporated Society for Promoting Experiments in Horticulture

IMPERIAL MYCOLOGICAL INSTITUTE
7 JUNE 1937

ANNUAL REPORT

(TWENTY-FOURTH YEAR)

1936

EAST MALLING RESEARCH STATION

EAST MALLING

KENT

1st January, 1936 to 31st December, 1936

Free to Associate Members.
Price to Non-Members, 5/-
post free.

Published
May, 1937

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
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PRINTED IN GREAT BRITAIN BY HEADLEY BROTHERS
109 KINGSWAY, LONDON, W.C.2 ; AND ASHFORD, KENT

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From Maidstone by the Maidstone and District Motor Services Limited, every 20 minutes from Maidstone to East Malling Church.

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For Visitors coming by road Ditton Corner on the main London-Maidstone Road (with Red Lamp Danger Signal) is the turning to the Research Station.

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EDITORIAL

THE Station's Annual Report is now issued in two parts. That dealing with the general development and activities of the Station is published as a Supplementary Report which is presented by the Executive Committee to the Annual General Meeting; it is mainly for the use of our Committee and Members and is circulated separately to our Members.

The Annual Report of research work consists of four sections as follows:

I. The Experimental Farm.

II. General Review of Research Work, with Summaries of Papers published during the Year.

III. Preliminary Research Reports and Progress Reports.

IV. Bulletins for Fruitgrowers.

In the General Programme of Research Work the numbers accompanying the projects set out in Section II correspond to those of last year. This Section includes complete lists of papers published by the Staff during 1936 together with summaries of those papers not readily available to the majority of our Members. Papers published in our Annual Report for 1935 are mentioned in the lists but not summarized since they are either already in the hands of our Members, or can be purchased from the Station.

The general editorship of this Report has been undertaken by Dr. Wormald, but heads of Sections are responsible for the sectional reports.

R. G. HATTON.

In the Coronation Year it seems appropriate to reproduce this photograph of His Majesty taken in 1934 when, as H.R.H. the Duke of York, he visited the Research Station.

(Photograph reproduced by courtesy of "The Kent Messenger.")

Section I

THE EXPERIMENTAL FARM

By J. AMOS, F. H. BEARD, M. H. MOORE, A. C. PAINTER and B. L. WATES, with introduction by R. G. HATTON

INTRODUCTORY.

We would once again repeat the remarks that have formed the introduction to this section of the report in previous years, as it is very essential that they should be borne in mind when considering the results obtained.

The total area of the Research Station is now approximately 150 acres (Great East Field 22 acres, Egham Field 40 acres, Church Field 20 acres, Newgates Field 25 acres, Upper Grub and Newgates Shaw 13 acres and, in addition, the areas now managed on behalf of our Trustees, Kiln Field 18 acres, and Deadman 12 acres). However, quite a considerable proportion of this area (approximately 15 acres) is occupied by buildings, approaches, innumerable headlands to comparatively small experimental plots and even to planted areas which can never be commercially productive (approximately another 15 acres). In addition, many of the plantings (approximately 18 acres) are still quite young and are producing little or no return. Again, varieties of problematical commercial value have frequently to be chosen deliberately for planting in order to study the very troubles for which the grower is seeking an explanation. Finally, even amongst the yielding areas there are inevitably the " control " plots, the unpruned, unsprayed, unmanured, etc., which bring down the standard of the whole. The picking and marketing is often complicated by the very large number of varieties grown and the small plots into which many of the trials are divided, e.g. strawberry and raspberry trials may consist of as many as 100 or more separate plots, each of which has to be picked and recorded separately, thus appreciably increasing the cost of picking and the amount of handling which, in its turn, renders it difficult to get the fruit on to the market in the best condition.

As the subsequent account clearly shows, the combination of an unpropitious season with these numerous experimental limitations has resulted in the production of a considerable quantity of fruit of which we are far from proud. Whilst many growers were successfully controlling their troubles along the lines of our normal recommendations, the Station's energies were so divided that we were often unable to complete our own schedule.

Again, it was perhaps unfortunate that the very season, when the Institute had arranged to test out on a considerable scale its own " doxies " in relation to clonal strawberry runner raising, should have proved to be the wettest for many years and most unpropitious for this particular purpose. If runner beds are to be rogued for " yellow-edge " virus, it is essential that they should be kept clean of weeds, and the Station had a salutary lesson in appreciating what this could mean, not only in the amount of labour involved but in the frequent disturbance of the runners themselves. After the spring plants have been lifted and distributed, it is intended that these experiences shall be dealt with in much greater detail for the benefit of would-be raisers of clonal " disease-free " stocks. Meanwhile, the East Malling practice of giving its theories a commercial trial before recommending them to others has as usual proved very valuable.

Owing to all these experimental exigencies it is only on comparatively small areas that our own ideal routine of cultural and spraying methods can be carried out. We

would ask our grower readers to bear all these foregoing facts in mind in judging the results on an experimental farm. East Malling must not be looked at as a farm mainly demonstrating how things should be done ; only too often the right ways can only be found out after eliminating a succession of wrong ones, and it yet remains for some Educational Authority to demonstrate on a commercial scale the combination of right findings of research and put them in their economic frame. This point of view is being emphasized because we believe that our annual report on the farm can profitably be developed in some detail, provided it is realized that we are not claiming to tell the story of a commercial holding run on up-to-date lines, but merely to state in terms of market value some of the experiences gained from sale of fruit from our experimental plots.

(R.G.H.)

FARM REPORT

CULTURAL.

Following upon the almost complete failure of our fruit crops in 1935, when the blossom was destroyed by frost, all fruit trees and bushes, with few exceptions, produced an abundance of " bud " and blossom during 1936. However, the spring months were not without anxiety and once again we were very near disaster, for on the night of 14th April, when most cherries, plums and bush fruits were in bloom, 14 degrees of frost were recorded. Although the damage was not so general as in the case of the frost in May of the previous year certain fruits were seriously affected. Whilst the blossom of standard plums and sweet cherries showed little damage, the unopened flower buds on both bush Morello and Kentish Red Cherry were completely destroyed. The damage to the bush fruits was more variable. Whilst gooseberries were a complete failure, in the case of both red and black currants it was noted that the earlier flowering varieties which happened to be open at the time were the ones frosted. This was naturally reflected in the crops harvested; in black currants, Goliath, which was unopened at the time of the frost gave the best set of fruit, and similarly in the case of red currants, the late flowering Wilson's Longbunch gave the heaviest yield. Both raspberries and strawberries showed considerable damage, but pears and apples were not affected. May was a month with dry weather and average sunshine and although a frost occurred on the night of the 2nd, causing much damage to potatoes and market garden crops, none was noted on fruit crops. During June and July heavy and continued rainfall occurred. The resulting humid conditions favoured the spread of disease and made the marketing of soft fruits a difficult one. In the case of strawberries, much of the fruit rotted in the field and frequently whole consignments became covered with moulds during a single night *en route* to the market. Great difficulty was also experienced in the management of hops ; excessive moisture encouraged rapid and rank growth of the bine, and was ideal for the spread of Downy Mildew. Spraying was continually held up but it was possible to get on sufficient Bordeaux mixture which, even under such adverse conditions, checked the spread of the disease. Fortunately the hot, dry and sunny weather during the latter half of August, combined with further spraying, enabled us to gather in an almost disease-free crop. Our plum plantations at this period resembled " hop fields ", for almost all varieties had to be supported by poles owing to the heavy set of fruit. Both apples and pears in many instances had to be given support, so great was the weight of the crops, and, as will be seen from our market section, this was the heaviest tonnage of fruit in the Station's history. Conditions during September and October were not ideal for harvesting and recording such heavy crops of top fruit, heavy rains and gales causing considerable damage in the way of dropped fruit. Picking was not completed until the end of October and, owing to insufficient storage room, much of the fruit had to be

left out in the plantation, and consequently was not at its best when it did eventually reach the pack house. November was a very wet month, some 4·3 inches of rain being recorded. December was, however, more open, colder, and with frequent high winds.

Fresh Plantings, Grubbing, etc.

Great East Field.—Owing to the trees becoming over-crowded, the remaining two acres of twenty-two-year-old apples in the original Pruning Trials have now had alternate trees removed. Branch and root weights of these were recorded. The only available area for fresh planting, that from which trees were grubbed in 1934, has now been planted with Royal Sovereign strawberries. These are being used to study the spread and transmission of virus disease under field conditions.

Egham Field and Church Field.—Two acres of eight to sixteen-year-old gooseberry bushes interplanted between pears, and one acre of thirteen-year-old red currants under apples have been grubbed. Except for very small areas, which are being used for nursery material, the whole of these fields are now fully planted up.

Newgates Field.—The five acres occupied by strawberries from 1932 to 1935, has, after having grown a crop of wheat for one year, again been planted with runners from our clonal stocks of Royal Sovereign and Tardive de Leopold. A section is also being used to continue for a further season the time of planting trials.

Upper Grub.—With the exception of a small piece which is planted with hops and black currant seedlings, the whole of the remaining nine acres is given to the raising of nursery material and to intensive nursery trials of new rootstocks, etc.

Kiln Field.—The eight acres of twenty-two-year-old apples, interplanted with plums, on the east side of this field, has had the latter removed, and on the west side the filler trees between the Bramleys have also been grubbed. The removal of these trees should greatly benefit those remaining and also enable cultivation and spraying to be carried out more effectively. This plantation as a whole is an excellent example of a badly thought-out commercial plan, which has made any logical thinning operations most difficult. It was taken over by the Station in 1934.

Deadman Field.—The whole of the six acres planted with clonal Royal Sovereign strawberry plants was used for the production of runners, and the majority of these were sent out to members during the autumn. It is proposed to crop the parent plants during the coming year. The six acres of arable reserved for future strawberry experiments was again left unmanured and cropped with oats. (J.A.)

Marketing.

For the second year in succession frost took a heavy toll of the soft fruit crops. Gooseberries were a complete failure and the yields from raspberries, black currants, and red currants all were poor. Acid cherries, too, suffered severely, the Morello crop again being wiped out and Kentish Red faring little better. On the other hand plums, apples, and nearly all varieties of sweet cherries, the fruit of which had been entirely destroyed by frost the previous year, produced bumper crops. Pears, too, did well.

Very fair prices were obtained for what soft fruits there were, also for pears and the better samples of cherries. Markets were, however, glutted with plums and apples to an even greater extent than in 1934, and prices moved to a level lower than any experienced for very many years. Nevertheless as a rule good quality fruit found a steady outlet at prices which it is thought were not altogether unsatisfactory to the grower who had a high proportion of his crop of this standard, as in most cases lower prices were offset to

a considerable extent by higher yields. Small and poor grade fruit, however, could only be moved with difficulty and at quite unremunerative prices. Of this there was far too much on the markets and it is surely a sign of the times that, whereas three or four years ago fruit of this description would often fetch a price that made it worth while to market, such is no longer the case—in fact there is little doubt that, with increasing home production and the large quantities of well-packed and graded overseas fruits of all kinds now on the markets throughout the year, the time has come when in a normal year such fruit simply does not pay for production.

It would seem that if the home grower is to compete successfully with fruit from overseas and make fruit-growing pay, then the general standard must be raised with a view to producing a higher proportion of good quality fruit and eliminating the large amount of rubbish now often seen on the market.

There is also another factor, the importance of which does not seem to be sufficiently realized, and that is continuity of supply. A comparison between the prices obtained this year for much of the National Mark English fruit and boxed standard Canadian and American varieties gives food for thought. One of the reasons for the steady demand and relatively good prices obtained for the latter is thought to be due to the fact that it is available in quantity and on demand. For the large grower this problem of continuity of supply may not present any insuperable difficulty, but for the small grower it is, under present conditions, obviously not so easy a matter. No continuity of supply, however, can be of any use unless the fruit is of sufficient quality to create the necessary demand for it.

The gas store chambers were used for cold storing a quantity of plums, and of apples some 6,000 bushels of Bramleys, Edward VII and Lanes were placed in gasstore in October. These last have not yet been marketed at the time of writing.

Gross receipts from fruit, apart from that now in gas store, amounted to approximately £3,500, made up as follows:

	£
Strawberries	15
Raspberries	220
Red Currants	50
Black Currants	155
Gooseberries, loganberries, blackberries, and peaches	45
Cherries	95
Plums	885
Pears	440
Apples	1,600

Unless otherwise stated prices are those obtained for the main crop, odd consignments at the beginning and end of the season not being taken into account.

Individual Crops.

Strawberries.—(Area under cultivation—6 acres used for runner production in Deadman and two small experimental plots, comprising about ¼ acre.)

The quantity dealt with was negligible, only some 4½ cwt. of fruit being marketed.

Raspberries.—(Area under cultivation—about 4 acres of three-year-old Lloyd George and 1 acre of two-year-old new seedlings in Newgates Field. Also small patches of new seedlings and odd varieties in Egham Field.)

In the Lloyd George plantation frost killed off much of the early blossom, especially on the lower lying parts, the crop from the 4 acres only amounting to somewhat over

5¼ tons. The fruit was mainly small with the result that the greater part—some 4½ tons—had to be marketed in tubs for jam. A small quantity of better quality fruit—12 cwt.—was marketed in 3 lb. chips at prices ranging from 4d. to 9d. a lb. Jam fruit made £32 to £34 a ton.

Including 14 cwt. from the odd plots the total raspberry crop amounted to a little over 6 tons for which a gross return of £218 or £35 a ton was obtained.

Gooseberries.—(Area under cultivation—2 acres interplanted between bush pear trees and consisting of a variety collection of Careless, Freedom, Greengage, Gunner, Keepsake, Leader, Leveller, White Lion and Whitesmith, the bushes being from eight to sixteen years old. Also ¼ acre of five-year-old bushes. Both in Egham Field.)

The 2 acre plantation was to have been grubbed at the end of the season but frost so reduced the crop that it was decided to grub it at once as the small amount of fruit remaining would not have paid for cultivation.

No quantity was picked from the five-year-old bushes.

Red Currants.—(Area under cultivation—about ¾ acre interplanted between apple trees and consisting of some twenty odd varieties from eleven to thirteen years old. Also ¾ acre of six-year-old bushes interplanted between pears, which is being used for a variety and cropping trial. Both these plantations are in Egham Field.)

Frost again caused extensive running off, only some 15 cwt. of fruit being picked from the older bushes and 8 cwt. from the younger plantation. Prices ranged from 3d. to 6d. a lb., and gross receipts amounted to £51 or an average of a little over 4½d. a lb. The fruit was marketed in 6 lb. chips.

Black Currants.—(Area under cultivation—2 acres of four-year-old Baldwin and Wellington Triple X and 2 acres of three-year-old mixed varieties in Newgates Field, 4 acres of three-year-old Wellington Triple X in Church Field, and ½ acre of new seedling crosses.)

Black currants also suffered severely from frost, the total yield from all plots only amounting to 2 tons 13 cwt. The gross amount received was £155, prices ranging from 5½d. to 7d. a lb. with an average of rather over 6¼d., thus being almost identical with the previous year.

Most of the fruit was marketed in 4 lb. chip baskets instead of in 6 lb. chips as heretofore, that being the package favoured by the salesmen to whom our fruit was consigned.

Cherries.—(Area under cultivation—⅖ acre of thirteen- to fifteen-year-old Morellos, planted at 12 by 12 ft., ½ acre of ten-year-old Morellos, ⅜ acre of nine-year-old Kentish Red and ⅓ acre of Carnation and young Morellos, all at 15 by 15 ft., in Egham Field. In addition ¼ acre of eight- and nine-year-old Morellos in Newgates Field held at the disposal of the Pathology Section for spraying trials. Also a miscellaneous variety collection of sweet cherries.)

As far as acid cherries were concerned the season was a blank one. For the second year in succession Morellos were a complete failure, the flowers being killed by frost in April long before the blossom opened. Kentish Red were also cut by frost and yielded little more than 7 cwt. Carnation, too, was a very light crop.

Sweet cherries, on the other hand, with few exceptions set a heavy crop, the variety collection, many trees of which are now coming into bearing, producing 2½ tons of marketable fruit. Wet weather, however, especially towards the end of the season, caused much cracking and consequent wastage. Black cherries on the whole sold well, but other kinds, unless a good sample, as a rule sold poorly.

In all the cherry crop amounted to rather over 3 tons, bringing in £96.

Plums.—(Area under cultivation—3 acres of fourteen-year-old and 2 acres of eleven-year-old trees interplanted with cherries in Egham Field, 2½ acres of eight-year-old trees in Church Field, also interplanted with cherries, ½ acre of Czars and Myrobolans planted for windscreen purposes in Newgates Field, and 3½ acres of approximately twenty-year-old trees in Kiln Field.)

Following last year's almost entire absence of fruit, practically all varieties set heavy crops, notable exceptions being Myrobolan, President, Monarch and Utility. President, though the trees are now fourteen-year planted, has only cropped once—in 1933; usually the yield has been small. Utility, now eleven-year planted, has yet to set its first crop. This variety makes an extremely large and vigorous tree, which blossoms early. The fruit is of good flavour but is very liable to crack, especially in wet weather, and for that reason it would appear to be necessary to pick it well before it is ripe.

The heavy set necessitated an extensive thinning programme. The fruit of Victorias, Czars, Pershore Egg, and the older trees of Giant Prune were all thinned to 1 in. apart, commencing on 15th June and continuing into the first week in July. With Victoria this involved removing on an average somewhat over half the crop, with Czars rather over one-third and with Pershore Egg approximately one-half. For Czars thinning to 1 in. gave on the whole satisfactory results, but in the case of Victoria and Pershore Egg, which were carrying very heavy crops (as much as ten or more half-sieves a tree), it does not appear to have been drastic enough under the conditions prevailing, the proportion of fruit of National Mark standard in no case exceeding some 30 per cent. (See Appendix 1.)

The total marketable crop which, like apples and pears, was the largest experienced in the history of the Station, amounted to some 5,450 half-sieves, or 58 tons, an increase of 18 tons over 1934. The greater portion of this consisted of Czars (1,600 half-sieves) and Victorias (2,140 half-sieves).

A mechanical grader was used for the first time and proved of great value in dealing with the large quantities of fruit. It was both more accurate and very much quicker than hand grading.

Early Rivers, which obtained from 3s. 6d. a half-sieve to 4s. 6d. a 12 lb. chip according to quality, sold well, as did early consignments of Czars. The price, however, fell rapidly, good samples of National Mark fruit selling for as little as 1s. a 12 lb. chip. Smaller fruit fetched anything between 1s. 6d. to 2s. 6d. a half-sieve. Towards the end prices hardly covered the cost of picking and marketing, and in Kiln Field some of the fruit was left on the trees.

Myrobolans were a light crop, having been somewhat badly frosted. What fruit there was, however, was of good quality. Up to the middle of August they sold well, fetching 4d. to 5d. a lb., but after that, in common with other varieties, the price fell away, going as low as 1d. and 1½d. a lb.

National Mark Pershore and Purple Egg fetched from 1s. to 1s. 6d. a 12 lb. chip, and smaller fruit from 1s. 3d. to 2s. a half-sieve.

Victorias, as might be expected, were a little better market, but here again, except for the better samples, prices ruled low. Fruit of National Mark standard marketed direct from the tree fetched from 1s. 6d. to 3s. a 12 lb. chip, and smaller fruit from the equivalent of 1s. 6d. a half-sieve up to 2s. a 12 lb. chip. A considerable quantity of fruit was held over in cold store and marketed between 10th and 25th September, an increased price of from 6d. to 1s. a 12 lb. chip being obtained.

Giant Prune and Pond's Seedling followed much the same course as Victoria. The quality of the Pond's Seedling, however, was affected to a considerable extent by Sooty Blotch.

Warwickshire Drooper also suffered from a rather severe attack of this disease, but, as usual, clean samples of this variety sold well, fetching anything from 2s. to 6s. a 12 lb. chip. The fruit was marketed between 15th September and 10th October, prices varying little whether marketed direct from the tree or from cold store. Sooty Blotch reduced the price of fruit so affected by anything from 6d. to 2s. a 12 lb. chip. A method of cleaning the fruit is described on page 196. This is somewhat laborious and needs a little care, but would almost certainly pay where the attack is at all severe and a good price is being obtained for clean fruit.

The trees of Cambridge Gage on Church Field gave their first crop, a nice sample of good sized fruit. 75 per cent. of this came up to National Mark standard and sold at prices ranging from 3s. to 6s. a 12 lb. chip.

Damsons, which were also a heavy crop, were placed in cold store and marketed during the first ten days of October at 1s. 9d. to 2s. 6d. a 12 lb. chip compared with 1s. to 1s. 3d. obtained in the middle of September.

Gross receipts for plums amounted to £885 or an average of 3s. 3d. a half-sieve for those marketed. If 1s. 6d. is taken as the average cost of picking and marketing 24 lb. of fruit this represents a net return of 1s. 9d. a half-sieve. Nearly two-thirds of the crop was marketed in 12 lb. chips, and the remainder in half-sieves.

The equivalent of 1,870 half-sieves was marketed under the National Mark Scheme. A table showing the percentage of National Mark fruit produced for certain varieties is given in Appendix 1, and some average prices obtained in Appendix 2.

Pears.—(Area under cultivation—6 acres in Egham and ½ acre in Church Field, 5 of which consist of a number of different varieties from ten to seventeen years of age. The other acre consisting of six-year-old trees is just coming into bearing.)

Pears on the whole cropped well, with the exception of Pitmaston Duchess and Emile d'Heyst, which were again rather on the light side. There had been none in 1935 except in the case of Conference. Only Hessle and Fertility were thinned, but it would probably have paid to thin Dr. Jules as well.

The total quantity marketed amounted to 1,350 bushels, Conference contributing the largest individual amount, viz. 370 bushels. This total would have been appreciably larger had not exceptionally strong winds been encountered at the beginning of September when large quantities of fruit were blown down. Some 440 bushels were marketed under the National Mark representing about 45 per cent. of the crop of those varieties allowed to be marketed under the Scheme. That the percentage was not larger was mainly due to the proportion that was under size.

Total receipts amounted to £440 giving a gross average return of 6s. 5d. a bushel.

Apples.—(Area under cultivation—23 acres in Great East, Egham, and Church Fields, consisting of many different varieties, ranging from six to twenty-three years of age. Also a further 14 acres of approximately twenty-year-planted trees in Kiln Field.)

Like plums, apples, after last year's failure, in nearly every case set heavy crops.

With the large area of plums requiring attention and only a certain amount of labour available, it was not possible to do as much thinning as was desired. Wherever possible, however, such varieties as Early Victoria, Miller's Seedling, White Transparent, Grenadiers and Duchess' Favourite were thinned, as was also one plantation of Worcesters. Bramleys and Lanes were left unthinned as it was hoped to gas store the larger proportion of the crop, and judging from past experience, small fruit was less likely to be affected by low prices later in the season. It was also thought that after a year of complete rest the trees might mature heavy crops of average size.

For experimental reasons it was not practicable to do more than " single " Early Victorias, which meant spacing the fruit from 3 to 4 in. apart. Under our conditions this was not nearly sufficient for producing fruit of marketable size. Miller's Seedling, White Transparent, and Duchess' Favourite were thinned to about 4 in. apart. Here again the thinning might with advantage have been more drastic. With the exception of Duchess' Favourite all the above were some twenty years old.

The total quantity of marketable fruit amounted to approximately 14,500 bushels, the principal yields being :

Bramley's Seedling	5,700 bushels.
Lane's Prince Albert	2,700 ,,
Worcester Pearmain	1,480 ,,
Lord Derby	730 ,,
Cox's Orange	620 ,,

There was an all round drop in prices compared with previous years, an even lower level being reached than in 1934. Early consignments of Beauty of Bath sold fairly well up to 6s. a half-sieve, but prices soon dropped to about 3s. for the better samples of Fancy grade, and as little as 1s. 6d. and 2s. for poorer samples. Gladstones were practically unsaleable and the larger portion of the crop was left unpicked. National Mark Miller's Seedling made up to 3s. 6d. a half-sieve—the colour, however, was not up to the standard of 1934, possibly due to lack of sunshine. Extra Fancy Worcesters of $2\frac{1}{4}$ in. and over sold on an average at 3s. to 4s. 6d. a half-box, Fancy grade of the same size at 2s. 6d. to 4s. a half-box, and Domestic standard at 1s. 6d. to 2s. 6d. a half-sieve. Prices of Allington, Rivals, and Blenheims were all appreciably lower, rarely exceeding 3s. Cox made a better showing but here again prices were on a lower level. Extra Fancy fruit, i.e. of $2\frac{1}{4}$ in. and over, marketed between the middle of November and the middle of January, made from 6s. 6d. to 8s. a half-box, Fancy fruit, i.e. over 2 in. in size, from 4s. to 7s. a half-box, and Domestic standard from 3s. 6d. to 6s. a half-sieve. Barnack Beauty, which did quite well in 1934, did not fetch a higher price than 3s. a half-sieve. There was little market for lesser known varieties.

Cooking apples, unless of good size and quality, were extremely difficult to sell. Except for one or two early consignments Grenadiers made no higher price than 4s., Derbys 3s. and Lanes 4s. a bushel in the London markets. Small fruit went at prices well below these figures.

Practically the entire Bramley crop—some 5,500 bushels—300 bushels of Edward VII and 300 bushels of Lanes were placed in gas store during October. It is expected that a start will be made with marketing these early in March.

Apart from the fruit put into gas store some 8,600 bushels have been sold for approximately £1,600, giving an average gross return of 3s. 9d. a bushel compared with 5s. in 1934. Of these approximately 4,400 were marketed under the National Mark, representing a little over 60 per cent. of the crop of those varieties eligible for marketing under the scheme. (A.C.P. and B.L.W.)

Hops.—(Area under cultivation—9 acres—$5\frac{1}{2}$ acres of Professor Salmon's seedlings in Egham Field, $3\frac{1}{4}$ acres devoted to cultural trials in Church and Egham Fields, $\frac{1}{4}$ acre of commercial varieties in Upper Grub. About 1 acre was not in full cropping.)

Weather conditions in the early part of the year were favourable and there was an extremely slight attack of the " basal spike " form of " Downy Mildew ". However, the exceptionally wet conditions prevailing during June and July caused a severe outbreak of Downy Mildew at a most critical time, during the formation of the burr. Fortunately applications of Bordeaux mixture and a dry August checked the spread of

the disease and with few exceptions the hops were picked free from any attack on the cones. Three sprayings with home-made Bordeaux mixture were given throughout the garden, whilst the late varieties received an additional late spraying.

For the second year in succession the gardens suffered from a severe gale at picking time ; although there was considerable browning of the cones, the damage was not nearly so severe as in 1935 and it was possible to pick nearly all varieties.

The total growth of hops was nearly $7\frac{1}{2}$ tons, only slightly less than the record year of 1934. This heavy crop was due entirely to the fact that several of our recent plantings have now reached maturity ; actually most varieties gave yields rather lower than normal.

Prices obtained for this season's growth are on the whole slightly lower than in the two preceding years. This reduction in price is largely due to the fact that nearly all varieties suffered to a greater or less extent from the gales early in September.

Brewer's Gold (C9a) and the Manitoba Seedling (OQ22) realized the highest price, £11 per cwt. Four pockets of the early seedling P13 made £10 10s. per cwt. Six and a half pockets of the "Quality Hop" (OO63) realized £9 10s. per cwt. Eight pockets of "Brewer's Favourite" (OP21) fetched £9 per cwt. Our growth of Fuggles ($8\frac{1}{2}$ pockets) made £8 per cwt. It is interesting to note that for the first time the seedling L21 realized more than the Fuggles, ten pockets making £8 10s. per cwt. L21 was picked early and so escaped wind damage, whereas the value of the Fuggles was reduced in consequence of the damage. Mixed growths realized £8 5s. per cwt., which was 5s. per cwt. less than the previous year, but 5s. per cwt. more than was obtained in 1934. (F.H.B.)

APPENDIX 1.

Plums, 1936.

Table showing Percentages of National Mark Fruit produced for certain Varieties.

Variety.	Plantation.	Total quantity dealt with.	No. of plums to 1 lb.		% weight of National Mark Fruit.		% rejected for blemish.
			Extra selected.	Selected.	Extra selected.	Selected.	
Early Rivers	Plot 21	2 tons	—	21-25	—	44%	3%
	Medium heavy crop from well grown 15- to 16-year-old trees. Unthinned. Extra selected not kept separate.						
Czars	Kiln Field	8 tons	11-12	14-16	7%	60%	11%
	From a plantation which, until 3 years ago, was an ordinary commercial plantation. Trees about 20 years old. Medium heavy crop. Unthinned.						
	Plot 21	$1\frac{2}{3}$ tons	14	15	3%	59%	19%
	Medium to heavy crop from 15- to 16-year-old trees. Thinned to 1 inch apart.						
	Plot 29	$4\frac{1}{2}$ tons	—	16	2%	56%	12%
	Heavy crop from 12- to 13-year-old trees. Thinned to 1 inch apart.						

Variety.	Plantation.	Total quantity dealt with.	No. of plums to 1 lb.		% weight of National Mark Fruit.		% rejected for blemish.
			Extra selected.	Selected.	Extra selected.	Selected.	
	C.F.4	1¾ tons	—	16-19	Nil	27%	6%
	Heavy crop from 9- to 10-year-old trees which have always produced small fruit. Thinned to 1 inch apart.						
Victorias	Kiln Field	7½ tons	6-7	8-9	1·5%	25%	10%
	Very heavy crop from plantation which until 3 years ago formed part of ordinary commercial plantation. Thinned to 1 inch apart. Trees about 20 years old.						
	Plot 21	12⅓ tons	6-7	9	0·5%	16%	5%
	Very heavy crop from plantation of well grown 15- to 16-year-old trees. Thinned to 1 inch apart.						
	Plot 29	1½ tons	6-7	8-9	—	29%	8%
	Very heavy crop from plantation of 10- to 11-year-old trees. Thinned to 1 inch apart.						
	C.F.4	1⅓ tons	No record		0·5%	29%	3%
	Very heavy crop from plantation of well grown 9- to 10-year-old trees. Thinned to 1 inch apart.						
Purple Egg	Plot 29	1⅙ tons	—	15-16	—	23%	13%
	Medium to medium heavy crop from plantation of 12- to 13-year-old trees. Not thinned. Extra selected not kept separate.						
Pershore Egg	Plot 21	1 ton	—	15	—	31%	5%
	Very heavy crop from plantation of 13- to 14-year-old trees. Thinned to 1 inch apart. Extra selected not kept separate.						
	C.F.4	1¾ tons	—	16-17	—	17%	8%
	Very heavy crop from plantation of 9- to 10-year-old trees which has generally produced small fruits. Thinned to 1 inch apart.						
Giant Prune	Plot 21	⅖ ton	No record		7%	57%	16%*
	Heavy crop from 15- to 16-year-old trees. Thinned to 1 inch apart.						
	Deadman	3 tons	6-8	9-11	28%	50%	11%*
	Medium to heavy crop from 6- to 7-year-old trees. Unthinned.						
Pond's Seedling	Kiln Field	1¼ tons	5-6	8-9	39%	30%	19%†
	Medium crop from trees which until 2 years ago formed part of ordinary commercial plantation. Unthinned. About 20 years old.						
Greengage	C.F.4	⅔ ton	18	21-23	34%	40%	9%
	Medium to medium heavy crop (for Greengage) from plantation of well grown 9 to 10 year-old trees. Unthinned.						

* High percentage of blemished fruit due to over-strict grading.
† High percentage due to attack of Sooty Blotch.

APPENDIX 2.

Plums, 1936.

Crops and Prices for certain Varieties.

Variety.	Quantity marketed in half-sieves.	Average price per half-sieve of 24 lb.	Remarks.
		s. d.	
Early Rivers	180	6 6	
Czar	1600	2 7	
Pershore Egg	250	1 7	
Purple Egg	110	1 11	
Victoria	2150	3 0	Partly cold stored.
Cambridge Gage ..	100	7 5	Partly cold stored.
Giant Prune	320	4 4	Mostly cold stored.
Pond's Seedling ..	120	4 7	Mostly cold stored.
Damsons	220	3 10	Mostly cold stored.
Warwickshire Drooper	65	6 3	Partly cold stored.

(A.C.P. and B.L.W.)

Routine Spraying Programme.

The weather in January was, on the whole, unfavourable for spraying; the frequent occurrence of rainy and frosty periods hindered the work, and the tar-oil spraying was not completed until mid-February.

Pears were again not sprayed with tar-oil. They have now been omitted for four consecutive winters and, prior to 1936, there was no evidence of the need for a tar-oil spray. In 1936, however, a fairly severe attack of aphis occurred, making it imperative to spray the pears with tar-oil in the winter 1936-7.

The spring and summer, with the exception of May and the latter part of August, were remarkably wet and sunless. As a result, Apple Scab proved to be much more formidable than it was during the previous few seasons, and the control obtained was less satisfactory than hitherto. It is felt that this was largely due to uncertain weather in April, for this delayed the application of the green-bud spray while the trees remained in a very susceptible condition; indeed, this period may well have been the most critical of all in the current season, for the conditions were ideal for Scab, and the disease developed very rapidly. An extra post-blossom application of lime-sulphur was made on apples towards the end of July. This third post-blossom spray, though intended primarily to control late Scab-infection, probably helped also to control Sooty Blotch, a fungous disease very prevalent in 1936, yet seen to only a minor degree on apples in these plantations.

Where winter Petroleum oil was not used Red Spider became troublesome, although the weather conditions in 1936 would not be expected to encourage this pest. Attacks of Apple Capsid occurred in some plantations, thus making imperative in the coming winter, 1936-7, the wider use of Petroleum oil to stamp out the infestation.

Frequent sprayings with Bordeaux mixture were necessary from July onwards to keep Hop Downy Mildew in check. The wet weather ideally suited this disease as well as Apple Scab.

Black currants received only 2 per cent. lime-sulphur, instead of 8 per cent., for Big Bud. The currants were almost free from this pest, and the strong spray was considered rather wasteful in the circumstances.

The inadvisability, as regards spraying, of growing gooseberries beneath pears was again demonstrated, and was even more pronounced than in seasons when spraying is, perhaps, less urgent. The gooseberries are always in flower when the pears need spraying at a critical time for Scab and caterpillar, and one of the crops must take second place to the other. Moreover, the gooseberries are a hindrance to the sprayers and are certain to be damaged by hose pipes, etc. The gooseberries on Plot 36 were grubbed out before the petal-fall spray was given to the pears there.

A noteworthy feature of 1936 was the excessive injury to trees by copper-containing sprays and dusts, especially when these were applied early in the season. This is mentioned in more detail elsewhere in this report (p. 261).

The difficulty, common to most growers, of keeping pace with pest- and disease-control under adverse conditions was well brought out in the cool, wet season under review. It provides an opportunity to refer to the inevitable aggravation of such difficulty on a research station farm where experiments, as well as commercial practice, have to be considered. Routine spraying in such circumstances entails more than the straightforward application of spray-fluid to apples or pears on all plots at any given period. A block here must be sprayed while a block there must be omitted because it is special experimental material. The spray must not be allowed to drift through certain trees for the same reason, and, if screening is impracticable, the routine spraying must be done only when the wind is favourable. The presence of necessary unsprayed trees as " controls " for spraying trials, and of trees receiving experimental manurial treatments, some of which must render certain trees more susceptible than others to pests and diseases, further helps to complicate the issue and to make it more than usually difficult to grow quite clean fruit.

The Research Station reference number of each of the plots sprayed is given among the details below to facilitate comparison of the sprays applied to any one series of plants throughout the season.

The symbols used for the sprays are :

B.M.	Bordeaux mixture.
L.S.	Lime-sulphur.
A.	Lead arsenate paste.
N.	Nicotine.
S.S.	Soft soap.
G.	Spray gelatine.
Leth.	" Lethalate " Standard Wetting Preparation.

All sprays are referred to in quantity of concentrate used in 100 gallons.

Period.	Spray used.	Hosts.	Sprayed against.	Remarks.
1st Jan.-14th Feb.	Standard **Tar-oil emulsion** (5 gals.).	Apples, Plums, Cherries, Black and Red Currants and Gooseberries.	**Aphis.**	All plots. Pears omitted as in 1933, 1934 and 1935.
8th and 9th Jan.	Standard **Tar-oil emulsion** (10 gals.).	Morello Cherries.	**Aphis** and **Brown Rot** (*Sclerotinia laxa*).	Plots 29, 35.
3rd-5th March	Home-made **Petroleum-oil emulsion** containing 5 gals. Petroleum oil. 1 gal. oleine. 1½ lb. caustic soda.	Apples.	**Capsid** (*Plesiocoris rugicollis*) and **Red Spider.**	Plots C3, 2, 3, 4, 10, 11, 12, 13, 14, 15, 16, 18.
10th March	**L.S.** (3⅓ gals.).	Outdoor, trained Peaches.	**Leaf-curl** (*Taphrina deformans*).	At Ditton Lab. and on Plot 18.
3rd and 4th April	**L.S.** (2 gals.).	Black Currants (*just pre-blossom*).	**Big-Bud Mite.**	Plots N2 and C4 and odd groups elsewhere.
8th April	**L.S.** (2½ gals.) + **A.** (4 lb.).	Pears (*white-bud*).	**Scab** and **Caterpillar.**	Plots 20 and C3 (including certain apples).
	L.S. (2½ gals.) + **Derris** (2 lb.).	Pears (*white-bud*).	**Scab** and **Caterpillar.**	Plot 36. Lead arsenate could not be used against caterpillar because gooseberries growing beneath the pears were in flower.
15th-25th April	**L.S.** (2½ gals.) + **A.** (4 lb.).	Apples (*green-bud*).	**Scab** and **Caterpillar.**	Plots 3, 4, 10, 11, 12, 13, 14, 16, 30, and Kiln Field (west half).
28th April	**Flowers of Sulphur.**	Strawberries.	**Powdery Mildew** (*Sphaerotheca Humuli*).	Plots 35 and Upper Grub.
1st and 4th May	**L.S.** (2½ gals.) + **A.** (4 lb.).	Apples (*pink-bud*).	**Scab** and **Caterpillar.**	Plot C3 and Kiln Field (east half—which had no green-bud spray because interplanted plums were in full flower).
1st-7th May	**L.S.** (2½ gals.) + **A.** (3 lb.).	Apples (*pink-bud*).	**Scab** and **Caterpillar.**	Plots C2, 2, 3, 4, 8 (cordons), 10, 11, 12, 13, 14, 16, 18, 30, 31, 33, 35 and Kiln Field (west half).

Routine Spraying Programme, 1936 (*continued*).

Period.	Spray used.	Hosts.	Sprayed against.	Remarks.
19th May	**B.M.** (8 lb. bluestone, 12 lb. hyd. lime).	Pears (*petal-fall*).	**Scab.**	Plots 20, 27.
20th-22nd May	**B.M.** (8 lb. bluestone, 12 lb. hyd. lime) + **A.** (4 lb.).	Pears (*petal-fall*).	**Scab** and **Caterpillar.**	Plots 36, 20 (parts of trees were missed on 19th May as spraying was done in high wind).
25th and 26th May	**L.S.** (1 gal.) + **G.** (1 lb.).	Plums (*post-petal-fall*).	**Red Spider.**	Plots 21, 29, C4, Newgates.
26th-29th May	**L.S.** (1 gal.) + **N.** (8 oz.) + **Leth.** (8 oz.).	Apples (*petal-fall*).	**Scab, Red Spider, Capsid** and **Sawfly.**	Plots 2, 4, 8 (cordons), 10, 12, 13, 14, 16, 30, 31; 33, C2, C3, Kiln Field (east half).
	N. (8 oz.) + **S.S.** (8 lb.).	Apples (*petal-fall*).	**Sawfly** and **Capsid.**	Plots 5 (nursery), 10, 11, 16, C3. Lane's only.
	L.S. (1 gal.) + **N.** (8 oz.) + **G.** (1 lb.).	Apples (*petal-fall*).	**Sawfly** and **Capsid.**	Plot 35 (young trees), Kiln Field (west half). Lane's omitted.
4th June	**Derris** (2 lb.) + **S.S.** (5 lb.).	Apples.	**Red Spider.**	Kiln Field (west half). Lane's and Derby only.
18th-23rd June	**N.** (5 oz.) + **S.S.** (5 lb.).	Hops.	**Flea-beetle** (*Psylliodes attenuata*).	Plots C5, 26, 27, Upper Grub.
23rd June	**N.** (5 oz.) + **G.** (1 lb.).	Apples.	**Aphis.**	Plot 8 (young cordons).
24th June	**B.M.** (6 lb. bluestone, 15 lb. hyd. lime).	Walnuts.	**Bacterial Blight** (*Pseudomonas Juglandis*).	Plot 24.
29th and 30th June	**Derris** (2 lb.) + **S.S.** (5 lb.).	Raspberries.	**Raspberry Beetle** (*Byturus tomentosus*).	Plot N1.
30th June and 1st July	**B.M.** (8 lb. bluestone, 12 lb. hyd. lime).	Pears (*second post-blossom*).	**Scab.**	Plots 20, 36.
1st-8th July	**L.S.** (1 gal.).	Apples (*second post-blossom*).	**Scab** and **Red Spider.**	Plots 2, 3, 4, 10, 12, 13, 14, 16, 30, 35, C2, C3, Kiln Field (east and west). Lane's and Belle de Boskoop omitted.

Routine Spraying Programme, 1936 (*continued*).

Period.	Spray used.	Hosts.	Sprayed against.	Remarks.
16th and 17th July	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime) + **N.** (6 oz.).	Hops (*pre-burr*).	**Downy Mildew** (*Pseudoperonospora Humuli*) and **Aphis.**	Plots C5, 26, 27.
24th and 25th July	**L.S.** (1 gal.) + **G.** (1 lb.).	Apples (*third post-blossom*).	**Scab** and **Red Spider.**	Plots 13, 14, Kiln Field (east and west), Bramley's and Worcester only.
27th July-5th August	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime) + **N.** (6 oz.).	Hops (*during burr*).	**Downy Mildew** and **Aphis.**	Plots C5, 26, 27 and, without nicotine, 30a and Upper Grub.
12th-15th August	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime).	Hops (*post-burr*).	**Downy Mildew.**	Plots C5, 26, 27, 30a and Upper Grub.
21st and 22nd August	**Flowers of Sulphur.**	Strawberries.	**Powdery Mildew.**	Plots 3, 22, 28, Deadman, Upper Grub.
24th August	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime).	Hops.	**Downy Mildew.**	Plots C5, 26, 27, 30a.
27th August	**Flowers of Sulphur.**	Hops.	**Powdery Mildew** (*Sphaerotheca Humuli*).	Plots C5, 26, 27, Upper Grub.
29th August	**Flowers of Sulphur.**	Hops.	**Powdery Mildew.**	Plots C5, 26, 27.
4th-12th Sept.	**Flowers of Sulphur.**	Strawberries.	**Powdery Mildew.**	Plots 3, 22, 28, Deadman, Upper Grub.
10th Nov.	Winter **Petroleum-oil emulsion** (7½ gals.) + **N.** (10 oz.).	Young Apples.	**Woolly Aphis** (*Eriosoma lanigerum*).	Upper Grub.

(M.H.M.)

Section II

GENERAL REVIEW OF RESEARCH WORK

WITH SUMMARIES OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

In Relation to Tree Fruits.

ROOTSTOCK INVESTIGATIONS.

The recent issue of detailed reports upon the behaviour of the main stock-scion combinations of apples, plums, and pears on quince, up to the end of the first seventeen years, has to a large extent fulfilled the primary objective of these investigations.

The rootstocks in commercial circulation have proved to have a persistent and wide range of influence over a number of the most widely grown scion varieties. Indeed, the rootstocks have sometimes had such dominating effects upon the scions as no cultural or nutritional treatments have as yet been able to attain. The different combinations of stock and scion have been evaluated for their special purposes, and, unless some new unexpected aspect develops rapidly, it is unlikely that further detailed reports of these main field trials will be issued for some years.

At present, none of the trees concerned appears to have passed its prime, though abnormally heavy crops of 1936, following upon the complete " wipe-out " through frost in 1935, were generally harvested from even the shyest cropping combinations. So far as size of tree and man-power will allow, the routine records of growth and cropping are being maintained on these original orchards. Meanwhile, it has become possible to intensify the work upon other aspects which are ultimately designed to shed light upon the parts played by the roots, stems, unions and branches. (R.G.H. and J.A.)

1. Apple Rootstocks.

The outstanding feature of 1936 was the heavy cropping on the main trials.

The seventeen-year-old bush trees of Lane's Prince Albert ranged from an average of $8\frac{1}{2}$ bushels per tree on No. XII, by far the heaviest crop yet borne on this stock, to $2\frac{1}{2}$ bushels per tree on No. IX, which is around its mean. The approximate yield of these seventeen-year-old bush trees (193 to the acre) was 1,000 bushels per acre.

Many of the trees in the younger field trial of Lane's Prince Albert (11 years) on Long Ashton layered free stocks and East Malling vigorous types bore their first considerable crop.

The heaviest cropping bushes of Bramley's Seedling (17 years old) were those on No. XVI which averaged $14\frac{1}{4}$ bushels per tree, whilst those on Nos. I and II averaged $8\frac{1}{2}$ and $10\frac{1}{2}$ bushels respectively. Although there were only 96 trees per acre, the trees yielded over 1,000 bushels of fruit.

The bush Worcester Pearmains of the same age gave rather different results, the trees on Nos. XVI, II and I all yielding about 5 bushels per tree. Those on No. IX gave $2\frac{1}{4}$ bushels.

The bush Cox's Orange Pippin trees still gave a disappointing yield on most stocks. Those on No. II cropped best with $2\frac{1}{2}$ bushels per tree.

Bramley's Seedling, Grenadier, Lord Derby and Allington Pippin also yielded heavy crops in the half-standard trials.

Whilst the fruit on some of these experimental plantations is purposely left unthinned, it was hoped that the trees generally would be able to carry these somewhat abnormal crops after the complete rest of the previous year. However, the season was very deficient in sunshine, scab proved difficult to control and the fruit was often small and below normal in colour and finish. The harvesting of such large crops experimentally proved no easy matter, especially as several serious gales occurred.

Despite this, individual tree crop weight and size records were maintained throughout, and in certain instances colour grading was undertaken.

Since the original sixteen varieties of so-called " Paradise " apple stocks were isolated and described at East Malling, a number of other layered apple stocks, chiefly of continental origin, has been received for identification purposes. Clonal races of these have been started, the varieties botanically described and a small intensive test of five of them with Cox's as scion was budded in July. Since the original publication describing the " Paradise apple stocks " is still in demand and has long been out of print, the necessary data have been revised and checked for reissuing the descriptions, together with those of the new varieties, at an early date. (R.G.H. and J.A.)

Three reports dealing with *the behaviour of the Woolly Aphis immune Northern Spy as a rootstock* have been prepared. The first which has been published (E111) is a study of the ease, habit and depth of rooting young and mature trees on Spy stocks when compared with certain Malling rootstocks. It appears that Northern Spy has a very distinctive natural root habit and is not able to adapt itself to uncongenial surroundings, such as the deeper and less well aerated soil regions where other rootstocks seem quite at home. (See 12.) (J.H. and W.S.R.)

A second paper, now in the press, brings up to date the performance in the orchard of the variety Grenadier, when grown both as a half-standard and a bush on Northern Spy and other vegetatively raised rootstocks. It clearly shows the stunting effect of Spy upon this variety under East Malling conditions, and the consequent loss of size and weight of fruit. This is important in view of similar experiences with other varieties overseas. (J.H. and R.G.H.)

Inarching to improve trees on poor rootstocks is dealt with in a third report, also in the press. The experimental methods which were devised so that the results could be rapidly detected, and also preliminary results, are described. The immediate object was to see whether it was possible to improve the performance of eight poor trees of Grenadier upon Northern Spy and Crab H rootstocks in foliage and new growth; improvements resulted in the second year from inarching vigorous rootstocks (No. XVI) into these debilitated trees. Rootstocks inserted into or below individual branches affected those branches above, whereas those inserted into or below the junction between two branches affected not only these two branches but also others contiguous to them. One properly placed inarched rootstock may affect a whole tree. Whilst this preliminary experiment will be kept under close observation for the next few years, a more complete

investigation of the effects of inarching has been started. Forty-two stunted trees of Huesgen's Golden Reinette on No. IX rootstock have had different varieties and numbers of stocks inarched into their stems with a view to elucidating the principles upon which this operation works. (J.H., A.B.B., R.G.H. and W.A.R.)

The plans for the large-scale planting at different distances of dessert apples upon various rootstocks to elucidate the economic aspect have again been considered further, with the result that the required trees cannot be available before the autumn of 1939. (R.G.H. and J.A.)

Cordon Trials. The three-year-old Cox's Orange Pippin and Worcester Pearmain single cordons, on rootstocks Nos. I, II, IV, VII, IX and XII, are already showing clearly marked differences in vigour and cropping. Detailed records have been continued on this trial. (A.B.B.)

Mechanism of Rootstock Effect. The seven-year-old Lane's Prince Albert trees worked high and low on the stock stem, and directly upon vegetative and seedling piece roots have so clearly manifested in the orchard the influences expected from the rootstocks concerned (Nos. IX, II, XII and seedling) that some of them are now being used for intensive studies. Though the records have not yet been fully analysed it would appear that the trees with a long stem-piece are slightly more affected by the stock than those worked direct upon a piece root, yet those worked in the latter manner still exhibit the striking differences shown by the stem-worked trees. A number of the trees are being excavated in their entirety in the hope of detecting morphological differences in the roots, whilst series of sections from roots and stems are being microscopically studied to follow any change in structure of the rootstocks when worked in these different ways with Lane's Prince Albert. A number of photo-micrographs of these roots and stems have been taken and a report is in preparation. This anatomical study is being extended to the whole range of rootstocks growing under different soil and cultural conditions and when worked with "neutral" or "pre-potent" scion varieties. During the season, examinations of root sections have proved a valuable adjunct in identifying doubtful specimens sent for naming.
(A.B.B., R.G.H. and J.A.)

The attempt *to repeat the recorded performance of mature trees on unknown rootstocks* by raising clonal races from root cuttings and taking scions from the original individuals has now reached the stage when the first batch of maiden trees so reproduced can be planted up in a fresh location for long term orchard observations.
(R.G.H., J.A. and R.J.G.)

2. Pear Rootstocks.

Practically all varieties, including Doyenne du Comice and Beurre Hardy, grown on quince rootstocks at the Station, bore considerable crops of fruit which were again recorded for individual trees. The variety Pitmaston Duchess was a notable exception. Considering the size and age of these latter trees the yield was very poor, despite profuse blossoming. The progress of the investigations, initiated in the spring, upon the causes of non-setting of blossom is dealt with under 15.

The half-standard and bush trees of Dr. Jules Guyot and Reine des Poires worked upon layered free-pear stocks, now thirteen years old, fruited fairly heavily for the

first time. The former are now growing too rapidly to make it possible to continue to record complete wood measurements much longer. (R.G.H. and J.A.)

The pear cordon trials and the large-scale commercial tests have been postponed until sufficient clonal material of certain selected free-pear stocks is available. (R.H.G., J.A., R.J.G. and A.B.B.)

All the specimen trees of the clonal free-pear stocks bore some fruit this year. Full descriptions of these have been prepared for publication. These will show that the so-called French seedling pear stocks comprise a very wide range of varieties as was already suspected from the leaf characteristics. (J.A. and A.B.B.)

Seven trees, representing the four main groups, bore sufficient fruits to make it possible to initiate, in collaboration with the Department of Agriculture, Pretoria, an investigation into the problems of harvesting, transport and germination of pear seed from known individual parents. Although it has been possible to propagate vegetatively a wide range of free-pear stocks for experimental purposes, no simple economic method has as yet been established. Since these clonal rootstocks have been shown to influence individual scion varieties very differently, it is intended to ascertain how far seedlings raised from individual trees " breed true " to the parent and how far any method of grading can produce a fairly uniform race of rootstocks. (R.G.H., H.M.T. and R.J.G.)

Investigations into the " incompatibility " of certain pear varieties to certain quince and pear roots are described under 8.

3. Plum Rootstocks.

A second progress report, embracing the full details of these investigations to the end of 1934, has been published (E110). The behaviour of a large number of different combinations of stock and scion over periods of from 9 to 14 years has been reviewed and big differences in vigour and cropping demonstrated. The behaviour of certain varieties upon seedling and clonal races of Myrobolan and St. Julien was compared, and the performance of a number of varieties growing ungrafted upon their own roots and worked upon different clonal rootstocks was described. A number of rootstocks of local origin, none of which, with the exception of Pershore, proved outstanding, have been evaluated and the possible influence of rootstock upon certain diseases analysed.

These main rootstock investigations are being continued and individual tree weights together with data upon fruit size of very heavy crops of fruit were generally recorded in 1936.

While Myrobolan B and Brompton, Pershore and Mariana, and Common Plum have all stood the test of time creditably for particular purposes and scions, search is still being made amongst the many varieties of St. Julien, White Damas and Kroosgespruim for a stock which will have a dwarfing tendency, prove fruitful and be compatible with all varieties. Some fourteen selections, with suitable controls, budded with Victoria and Czar have now been under an intensive nursery test for three years. Whilst some already show signs of incompatibility with Czar, there is a wide range of vigour and earliness to blossom and to set fruit. A few selections appear to be giving dwarfed yet healthy trees. (R.G.H. and J.A.)

The trees of Victoria (very susceptible to Bacterial Canker) double-worked with resistant stems, such as Utility and Purple Pershore, on Myrobolan B roots and compared with trees on Victoria stems have now been in the orchard one season. The various pruning and spraying treatments to be superimposed were begun in 1936. (R.G.H., J.A. and H.W.)

4. Peach Rootstocks.

The trees planted in the open against a board fence once again failed to crop and it is not now considered worth while retaining the trees any longer. They will, as opportunity offers, be lifted and have tree weights and other characteristics recorded.

The six vegetatively propagated selections of Common Peach and three clonal races of Myrobolan plum (claimed to be compatible with peaches), budded in 1935 with Hale's Early peach, have now reached the maiden stage. The peach selections have produced normal healthy trees but only one small weak tree was produced by the Myrobolans. Brompton and Myrobolan B stocks planted alongside, and budded similarly, gave rise to healthy and unhealthy trees respectively. A further batch of stocks has been planted in order to repeat the experiment. (R.J.G.)

5. Cherry Rootstocks.

Sweet Cherry Scions. The two scion varieties in the field trial not so far seriously injured by bacterial canker, Early Rivers and Turkey Heart, yielded a moderate crop of fruit in 1936. Whilst the Mazzard rootstocks represented in the trial undoubtedly influence both the vigour and the fruitfulness of the trees, the range of influence produced by the stocks at present in use is almost certainly less than that shown by stocks for apples, pears and plums.

The uniformity trial of seedling Mazzard stocks from various sources has been badly injured by bacterial canker. The scion variety used, Napoleon Bigarreau, has unfortunately proved under East Malling conditions to be one of the more susceptible varieties.

A further nursery trial of three layered Mahaleb rootstocks, with a layered Mazzard for comparison, consisting of trees now one-year-old from the bud, already suggests that incompatibilities may occur in certain combinations of Mahaleb stocks and sweet cherry scions.

Acid Cherry Scions. For a second year in succession, frost destroyed nearly all the blossom of the trees in the rootstock trials. There is little so far to suggest that rootstock influence may reduce frost injury, either by increasing blossom hardiness, or by hastening or retarding the blossoming period. The earlier blossoming induced in 1935 by a Mahaleb stock was not repeated in 1936. (N.H.G.)

Ornamental Flowering Cherries. Some thirty varieties, mainly of Japanese origin, have now been collected with the special assistance of Captain Collingwood Ingram, with a view to studying the relationship to Mazzard and other rootstocks. Maiden and two-year-old trees have become available during the year, and a number have been planted out in permanent positions near the buildings. Whilst no definite incompatibilities with Mazzard stocks have yet been found, Mahaleb stocks seem generally unsatisfactory for these varieties. It is intended to continue propagation compatibility trials over a number of years since commercial nurserymen are not satisfied that the stocks they are using are the best for the purpose. (R.J.G. and N.H.G.)

PROPAGATION.

6. Preparation of Experimental Material.

The work of testing new rootstocks for ease of vegetative propagation has been continued. The new Woolly Aphis immune apple rootstocks are exhibiting big differences in the nursery and a considerable proportion of them have features generally associated with good commercial rootstocks. Selections will now be made, planted out and budded with commercial scion varieties.

The three hundred quince rootstocks, raised from seed collected in the Caucasus (see 32) and stooled, have been successfully budded with two varieties, generally found to be incompatible with commercial quince rootstocks, and a variety of wide compatibility. The buds will be encouraged to form maiden trees on the stools from which they will be severed a year later and planted out for a further study of the compatibility of the rootstocks with the scion varieties worked upon them.

The four-year-old apple trees, worked standard high on different "stem-builders", are now occupying all the space allotted to them in the nursery rows. Selected blocks of these will now be excavated in detail and final records of growth, total weight, etc., be made on the whole series before removal. (See 14.)

The investigations in connection with the technique of vegetative propagation have been continued in collaboration with the Physiology Section. (See 65.)

The two thousand seedlings of new crosses of apples, pears and plums, raised by the Plant Breeding Section and budded upon dwarfing rootstocks, have been removed from the nursery as maidens and planted permanently in cordon rows.

Sets of trees on a range of rootstocks have been raised for various sections, details of which will be found in sectional reports. (R.J.G.)

7. Nursery Technique Trials.

Trials of the effect of the presence or absence of the wood in the bud-shield have been repeated owing to the possibility that seasonal climatic differences may influence the results.

Whilst it is now possible for the manufacturers to produce suitable rubber budding-strips, the price has remained at a high figure and consequently search has been made elsewhere for a more economical strip. It has been found that strips cut from used bicycle tubes have been fairly satisfactory but a few tubes have yielded unreliable strips and it is therefore doubtful if this source of strips would prove popular in large nurseries. The need for reliable and economical strips is being borne in mind and further trials will be carried out as material becomes available.

A preliminary trial of the effect of sealing newly inserted apple buds with petroleum jelly, on the prevention of bud losses due chiefly to the depredation of the "Red Bud Borer" (*Thomasiniana oculperda* Rubs.) has been laid down on similar lines to the work carried out some years ago at Long Ashton by Staniland and Umpleby. (R.J.G.)

8. Compatibility and Incompatibility between Stock and Scion.

The annual study of *effect of environmental conditions* on compatibility of certain stocks and scions has been continued. The same combinations of stock and scion are being repeated over a series of years and the resulting successes and failures recorded together with weather conditions. The first three years' figures have been analysed and show big differences in the percentage of "takes".

In order to test the *effect of time of insertion of buds* upon compatibility, 100 buds of Hales Early Peach were inserted into each of three rootstocks—comprising known compatibles and incompatibles at intervals of a week from June to September.

Two Specific cases of Compatibility are under test. It had been reported that Myrobolan B, which had previously been compatible to all the varieties worked upon it, was incompatible to Oullin's Golden Gage. A trial was carried out using Victoria and Denniston's Superb Gages as control scions; whilst normal percentages of buds grew from all combinations, before the end of the season the trees of Oullin's Golden Gage showed distinct signs of typical incompatibility. The bud unions will be examined in the laboratory and the field trial repeated a second season.

A plum stock new to this country but sent on recommendation from Germany as " Ackermann's Plum " received a first trial in 1935 when it was budded with Victoria, which will normally grow on any plum stock, and with Czar and Hales Early Peach, both of which readily show incompatibility. The maiden trees of all varieties have been satisfactory, so that the stock will now undergo a more prolonged test.

It has been possible during 1936 considerably to intensify these studies on incompatibility in several other directions, especially with Pears, Plums and Peaches. The immediate object has been to obtain information upon the general and specific phenomena of incompatibility and upon its immediate and ultimate causes.

A study has been begun upon the *relative growth rates of the stock and scion*, worked and unworked, in compatible and incompatible combinations. Similar periodic records have been made of the root development. Differences have been found in the growth cycle of different rootstocks which may have a bearing upon their compatibility with certain scions.

A study of *the cambial growth* during the period of budding and grafting, by the stripping method described by Professor J. H. Priestley, has been carried out on worked and unworked trees. Certain differences have already been found at the time of budding between compatible and incompatible rootstocks.

A comparative study in *the water content of stems and leaves* of compatible and incompatible combinations and of unworked stocks has been made with suggestive results.

Investigations of the unions between stocks and scions have been developed along these lines. Studies of anatomical structure have been made and suggestive differences recorded. Unions have also been tested for water conductivity by apparatus specially designed for the purpose. Although there has been considerable variation between individual unions of similar combinations, there appear to be greater differences between compatible and incompatible combinations in the amount of water passing through the unions.

Thirdly, *a strength-at-union* test has been devised to measure the pounds of force per square centimetre of cross-sectional area required to break the union; striking differences have been recorded.

Finally, the possibility that incompatibility might at least in part be due to an attempted union between diploid and triploid varieties has been considered.

Reciprocal grafts of pear varieties have been made. Material for budding has been kindly supplied by Mr. M. B. Crane of the John Innes Institution. (W.T.C.)

9. Top-grafting and Frameworking Methods for Mature Trees.

Of the eighty thirteen-year-old trees of Newton Wonder worked with Laxton's Superb in 1935 in four ways, eighteen (rather more than 14 per cent.) have succumbed to the " Silver-leaf " disease (*Stereum purpureum*) and have been removed from the

plantation. Some of the remaining trees have suffered to a less degree and numerous small branches have been cut out. Though up to the present the rind-grafted trees have suffered more than the others, it would be unwise to draw conclusions as to the merits of the various methods at this early date.

Search is being made for economical and efficacious graft seals; ten substances were tested during the season, but so far none has proved of outstanding merit. Further trials are in progress.

The pruning of frameworked trees in relation to length and position of graft is under investigation with a view to accelerating the return of the tree to full cropping. (R.J.G.)

ROOT DEVELOPMENT.

10. Root Growth Investigations.

Detailed observations on the root growth of apple trees on various rootstocks have been continued in the "root observation trenches", which have glass panels fixed against the soil, from the surface to a depth of 4 feet. The more moist conditions of the soil in the summer of 1936 have afforded an interesting comparison with the dry conditions of the three previous summers. The data are still being summarized. (W.S.R. and M.E.R.)

11. Soil Moisture Meters.

Seven of the direct-reading soil moisture meters, developed here, have been in operation at the Station throughout 1936. They have been placed in fallow land, and in clean cultivated and grass orchards and have given satisfactory service.* A number of other instruments have been used in various experiments during the summer both here and in other parts of the country and reports of satisfactory functioning have been generally received. Certain difficulties, encountered with early models, such as corrosion and fading of the gauge dial, have now been overcome and the present form seems very suitable for continuous service in the field. Experiments are in progress to try to produce a more compact model for pot and greenhouse work.

Greenhouse and laboratory experiments with plants in pots containing moisture meters have provided further interesting information and it is proposed to extend this work before presenting the accumulated data. (W.S.R.)

12. Tree Excavations.

The root habit of Northern Spy apple has been investigated by detailed excavation of a number of young Northern Spy trees ranging from 2 to 6 years old. Young trees of Ivory's Double Vigour and Malling rootstocks Nos. I, II, IX and IV were excavated for comparison. A section of a seventeen-year-old tree, and also a complete fifteen-year-old tree of Grenadier on Northern Spy rootstock were also excavated. In all, forty-seven trees were excavated and some very distinctive characteristics of Northern Spy are indicated. This work has been published (E111) and the results are summarized on page 53. (See also 1.) (J.H. and W.S.R.)

SPECIAL ASPECTS.

13. Biennial Bearing.

A report issued during the year is summarized on another page (E99, p. 50). (T.N.H., N.H.G., A.C.P. and B.M.W.)

* See pp. 105 and 113 of this Report.

The trees of Allington Pippin, referred to in the above report, which began to crop more regularly as a result of drastic spur shortening early in the " off " year, have now been removed owing to the necessity for thinning the orchard. A repetition of this trial was begun in 1936 on certain trees of Early Victoria in the Pruning Plot. The first spur shortening in the " on " year, produced a marked effect on shoot growth and fruit size. (N.H.G.)

The intensive study of biennial bearing initiated in 1935 has been continued throughout 1936 in close collaboration with the Physiology and Biochemistry Sections. (See Sections III and IV.) (R.G.H. and P.K.S.)

14. Double Working.

The trees in the nursery trial of " stem builder " varieties of apples are now five years old from the first scion, and three years from the second. As they have become extremely crowded, it is proposed to conclude the trial by lifting all the trees and recording weights of head, stem, and root. Certain trees will also be excavated in detail. The existence of an influence of the intermediate stem variety on the vigour of the second scion is clearly demonstrated, but rootstock influence on both vigour and fruitfulness clearly predominates. The trees have provided useful data on the effects of crowding in nursery rows. (See also 6.) (R.J.G. and N.H.G.)

The older trials of both apples and pears are still providing fresh evidence of the influence of intermediate varieties. In 1936, two second scion apple varieties clearly showed an influence of the intermediate on time of ripening.

The nursery trial of pears on intermediates of Pitmaston Duchess and Orange Bergamotte has again demonstrated that the dwarfing influence of the Orange Bergamotte intermediate is not accompanied by anything like such a degree of greater fruitfulness as might be expected. The dwarfing occurs even amongst trees on pear rootstocks ; it may therefore be unconnected with a possible incompatibility between Orange Bergamotte and the quince rootstock. (N.H.G.)

15. Non-setting of Pear Blossoms.

Some fourteen-year-old trees of Comice were subjected in the spring of 1932 to three different treatments, viz. light dehorning, severe dehorning, severe dehorning coupled with top-grafting of some of the branches to Glou Morceau. In 1932, the year of treatment, the trees which had been lightly and severely dehorned but not top-grafted, gave an increased crop from a greatly reduced amount of blossom. Subsequent differences in crop do not appear to be significant although there is an indication that the crops from the top-grafted trees have been somewhat reduced by the treatment. Hand-pollination of the flowers of Comice with the pollen of Nouveau Poiteau gave only moderate results. The " sap transfusion " experimental trees yielded one or two fruits this year but no conclusions can yet be drawn.

(N.H.G., N.B.B. and H.M.T.)

The intensive study of various factors in the setting of pear blossoms is now in progress. In an attempt to correlate weather conditions with blossom setting, detailed records of rainfall, sunshine, wind, frost and soil moisture have been taken throughout 1936 for comparison with similar records to be taken in 1937.

Measurements of flower size have been taken on sample blossoms to see how far size of flowers is related to blossom-setting.

An intensive examination of sample blossoms for proterandry and protogyny failed to reveal significant differences in this respect. Investigations into various artificial aids to setting of pear blossom were carried out. Spraying trees with honey solution to attract pollinating insects has so far yielded negative results. A shelter of hop lewing (light coconut matting) was put round two plots and records taken of crop from comparable trees inside and outside the shelter. There were indications that the shelter factor might be important.

An intensive study of the viability of pollen from three shy bearers and from one free-cropping variety was carried out in the laboratory. The investigation showed that pear varieties react differently to different cultural solutions. There were indications of greater viability of pollen from the free-cropping variety than from the shy-cropping varieties.

An intensive study of the growth of pollen tubes during fertilization in a shy-cropping variety is being carried out in the laboratory.

Size records were taken weekly of developing fruits which had been hand-pollinated with a view to correlating size of fruit with " June-drop ". The records showed that the fruits which dropped at any one time were the smallest on the tree.

A study of the effect on blossom-setting of severe dehorning or heading back of fourteen-year-old trees of Pitmaston Duchess pear on quince gave significant results in favour of dehorning. It is hoped in 1937 to supplement this result by a trial involving the removal of two-thirds of the fruit buds on trees that are not dehorned.

A trial of branch and stem-ringing of fifteen trees of Pitmaston Duchess on quince yielded no significant results in relation to set of blossom during the year of treatment, but the rings have been reopened and further records will be taken.

A series of branch injections with water, urea, and urea plus phosphates was made to test their effect on " June-drop ". There were no significant differences in this respect between the treatments, but striking differences in shoot growth have been recorded.

A series of Doyenne du Comice pears on quince, aged nine years, was used for a trial of the effect on blossom set of tying down all the leading branches. The trees bore no blossom in 1936.

A series of Pitmaston Duchess pears on quince, aged fourteen years, was used for a similar trial. There were indications of a better set of blossom on tied-down trees, but the trees were very variable and the results were not statistically significant. These lines of work will be continued during the coming season. (D.N.S. and R.G.H.)

PRUNING.

16. Apples.

Seven of the eight varieties remaining in the original Pruning Plot bore in 1936 the heaviest crop in their history; in more than one case the crop was double the previous best. The only exception, Lord Derby, bore slightly more fruit in 1931, before the severe dehorning to which the trees were subjected.

It is now plain that certain varieties, particularly Cox's Orange, will continue to show the effects of the differential pruning in their early years throughout their lives. Nothing short of long continued prevention of cropping could now bring the " regulated " trees of Cox's (whose leaders have never been tipped), up to the performance of the regularly leader tipped trees.

The use of certain trees in the Pruning Plot for a further attempt to control biennial bearing by means of pruning is referred to above (13). (N.H.G.)

The summer and winter pruning of laterals on the apple cordons has been started. (A.B.B.)

17. Pears.

Most varieties in the original trial, now in their fourteenth year, cropped heavily. Individual tree records were taken. The series of trees which was originally left unpruned, has, after being thinned and worked back for the past three years, given heavy yields of good quality fruit. The only trees of Pitmaston Duchess to carry a reasonable crop were those which had been severely dehorned (see 15). In the younger trial, some of the varieties bore their first crop and this was almost entirely confined to those trees on which light leader tipping is carried out. (J.A.)

The experiment on the effect of three different methods of pruning on the growth and cropping of nine varieties of pear planted as single oblique cordons is being continued. These trees were planted as maidens on Quince A in February 1932. Crop records for the season show that the largest total yield was from the trees which had leaders and laterals pruned in the winter. Of the nine varieties in the trial, Williams's Bon Chrétien, Marguerite Marillat and Admiral Gervais gave the highest yields for the year. (N.B.B.)

18. Plums.

In the trial planned to study the relation between time of pruning and incidence of Die-back, one series of trees will be pruned in April and another in September. (See 3.) (J.A.)

19. Cherries.

The trees in the older Morello rootstock trial plot, left untouched when the rest were dehorned four years ago, were dehorned in 1936. Owing to frost, for the second year in succession there was little fruit. Growth was on the whole satisfactory. (N.H.G.)

THINNING.

20. Apples.

The experiments on three dessert varieties were continued during the past season on the same lines as previously. The results in relation to biennial bearing have already been published (E99) and a report dealing with other aspects is being prepared. (A.C.P. and B.L.W.)

21. Plums.

Advantage was taken of a heavy crop to test the relative effect of thinning the fruit of heavily laden Victoria trees to (*a*) one inch apart and (*b*) two inches apart. With (*a*) this involved removing on an average over 50 per cent. of the fruitlets and in the case of (*b*) over 60 per cent.

A preliminary survey of the results would seem to show that under the conditions prevailing, in neither case was the thinning sufficient. Where the plums were thinned

to two inches apart only 25 per cent. of the crop by weight came up to the National Mark standard for size (a minimum diameter of one and a half inches) and when thinned to one inch as little as 14 per cent.

Before making a detailed report, however, it is proposed to watch for any effect the thinning may have on next year's crop. (A.C.P. and B.L.W.)

MANURING.

22. Apples.

In the trial of nitrogen, potash and phosphate on young trees of Cox's Orange Pippin and Beauty of Bath a considerable crop was gathered and a storage experiment was begun in collaboration with the Ditton Laboratory.

The main experiment has now reached the stage when remedial treatments must be applied to the plots that have received no potash.

The comparison of the effect of 8 and 4 cwt. of sulphate of potash per acre on previously unmanured trees of Bramley's Seedling in bearing has been continued. The amount of Leaf Scorch was much the same with the two treatments, though in both cases it was less than before manuring began in 1934-35. Owing to seasonal variation, however, it is not safe to assume that this reduction is entirely due to the potash. Nitrogen was again withheld from some trees, and certain symptoms shown by the leaves, thought to be connected with this and also with the heavy dressings of potash, were observed.

On the plot of Bramley's Seedling under grass, the trees receiving 10 cwt. of nitro-chalk per acre had considerably darker foliage than those receiving 5 cwt., though this year the latter were also quite healthy.

In the preliminary experiment on time of application of nitrogen, the trees of Cox's Orange Pippin receiving sulphate of ammonia at different periods of the year showed striking differences in size and amount of foliage as well as in wood growth.

(W.A.B.)

23. Pears.

The preliminary field experiment has been continued and has shown that, with an annual dressing of 10 cwt. shoddy and 5 cwt. steamed bone flour, an application of 4 cwt. sulphate of potash and 3 cwt. sulphate of ammonia in spring had no visible effect on foliage or growth. (W.A.B.)

24. Plums.

When they come into cropping, the series of eight varieties of Damson on Myrobolan B will receive various quantities of nitrogen in order that its effect on biennial bearing and delayed fruit ripening may be studied. (W.A.B.)

IRRIGATION.

25. Effect of Artificial Irrigation.

The summer of 1936 was not suitable for artificial irrigation experiments, but it is proposed to continue this investigation as opportunity offers. (W.S.R.)

VARIETIES AND CLASSIFICATION.

26 and 27. Apples and Pears.

A number of new sorts have been added to the Collection of Varieties being grown as cordons here. (H.C.C.)

28. Cherries.

A short account, mentioned on another page, of the work on cherry varieties was published in 1936.

The variety collection has provided much information on varietal susceptibility to cherry bacteriosis. This is now being written up for publication. (See 74, below.) (N.H.G.)

SPRAYING AND TREE PERFORMANCE.

29. Observations in Collaboration with Insecticides and Fungicides Section.

Ever closer attention is being given to the reaction of tree condition upon susceptibility to disease.

BREEDING.

30. Apple Rootstocks.

The work of breeding new varieties of apple rootstock immune from Woolly Aphis, undertaken in collaboration with the John Innes Horticultural Institution, has been continued during the past year. A joint paper (D122) has been published outlining the progress made from the entomological, pomological and genetical points of view and indicating the chief conclusions which can be drawn from this work. From the genetical results it is tentatively concluded that immunity is determined by, and is dependent on, a certain balance of genetic factors and that it is governed by a number of genes the action of which is in part complementary and in part cumulative. Work during the year has been partly concerned with raising families for the purpose of confirming certain of the genetic conclusions.

A large number of seedlings, chiefly crosses between Northern Spy and many of the Malling series of rootstocks, are now undergoing propagation tests in the nursery and many of them are showing considerable promise.

Detailed records of the relative vigour and productivity have been kept on trees of the four Merton immune seedlings, Nos. 778, 779, 789, and 793 selected from a family No. II × Northern Spy, worked with Lane's Prince Albert. The trees are continuing to show noticeable differences in vigour and cropping.

While no new families have been raised from crosses between the Paradise apple rootstocks during the past year the search for seedlings of outstanding promise as new rootstocks has been continued among families raised in previous years. A number of seedlings from crosses between the more vigorous members of the Malling series are now undergoing tests for ease of rooting and a large number of selected seedlings have now been worked with the scion variety Lane's Prince Albert and are being carefully observed for early indications of their influence upon this scion variety. Differences in vigour and cropping are already appearing among the nineteen selections from the family VIII × IX raised at Merton in 1921 and now worked with Lane's Prince Albert. One

set of these trees, which has now been superseded by a more complete trial, was excavated during the past winter and revealed interesting differences in the morphology of the root systems. In addition, studies of the internal anatomy of the roots and of the water conductivity of the unions have been made.

Trees of Lane's Prince Albert on 180 seedlings from the families IV × IX and IX × VI, planted out with the object of providing information upon the inheritance of rootstock influence on the scion, are beginning to show striking differences in vigour. (H.M.T.)

31. Plum Rootstocks.

The work of raising improved varieties of plum rootstock has been continued. Several families were produced during the past year from crosses between the commoner commercial varieties. A number of families of seedlings are now undergoing propagation tests. A trial of 160 seedlings of *Prunus divaricata* collected in the Caucasus, Asia, etc., for cytological studies at the John Innes Horticultural Institution and worked with Czar at East Malling in 1932, is now completed. A small proportion of these rootstocks has proved to be incompatible with Czar and, while the trees showed considerable variation in both vigour and cropping, none of them proved markedly better as rootstocks than the existing series of selected Myrobolans. (H.M.T.)

32. Testing of Imported Wildings.

Tests for ease of rooting have been continued on apple and pear seedlings raised at East Malling from seed collected in the Caucasus and Turkestan. So far very few of them have rooted readily on the stooling method. The shoots of three hundred quince seedlings collected from the same sources, growing as stools, were budded in situ with the pear varieties Dr. Jules Guyot, Marie Louise and Conference, a technique for testing compatibility which should save much time and space. It is hoped that some of these seedling quinces may prove compatible with those varieties of pear which will not take directly on to the varieties of quince at present in commercial use. (H.M.T.)

33, 34 and 35. Scion Varieties of Apples and Pears and Shortening the Juvenile Period.

A number of crosses were made between varieties of apple immune to attack by Woolly Aphis and those of high dessert quality with the object of evolving new immune varieties of commercial value. Further crosses designed to provide information on the inheritance of fruit colour in the apple were also made. Many of the seedlings raised in earlier years are now beginning to produce fruits. In certain cases their appearance and flavour has proved sufficiently promising to justify their being selected for further trial. The trial of seedling apples worked on vigorous, slow cropping rootstocks and dwarfing quick cropping rootstocks again showed that the rootstock plays a very important part in shortening the juvenile period of seedling apples. Of the numerous trees which bore fruit during the past season almost all were on the dwarfing and precocious No. IX.

It has been proved that severe pruning definitely delays fruiting but no result has been obtained from attempts to induce earlier fruiting by restricting the root systems in pots or by growing them under glass. A large trial of seedling apples worked on No. IX is being planted out. Numerous crosses between the leading varieties of dessert pears have been made with the object of producing new varieties of outstanding quality and flavour. (H.M.T.)

MARKET QUALITIES.

36. Market Problems.

Investigations are being continued with regard to the different methods for the marketing of fruits with special reference to the influence of such factors as variety, stock, season, thinning, manuring, and cultural operations and their effect on market value. (A.C.P. and B.L.W.)

SOIL TYPES AND PLANT PERFORMANCE.

37. Fruit Soils Survey.

The survey of the Hastings Beds has been completed and submitted to the Ministry of Agriculture. (N.B.B.)

To obtain a greater measure of the potentialities of some of the soil series found in the course of the Lower Greensand and Hastings Beds' surveys and of some of those soils not yet surveyed, small plots of apples have been planted where suitable sites could be obtained. Unfortunately none could be found on the Lower Greensand, but it has been possible to establish plots on the Curtisden and Lamberhurst series of the Hastings Beds, the Brickearth and the Clay with Flints.

The varieties are Cox's Orange Pippin and Worcester Pearmain and the rootstocks Nos. I, II, VII, IX and XVI.

The size of the plots makes it impossible to include more than two manurial treatments. These are potash with nitrogen and potash alone and should give an indication of the comparative potash and nitrogen requirements of the various soils.

Trees for subsequent excavation have been included at all centres.

(W.A.B., N.B.B. and W.S.R.)

Special Investigations.

WALNUTS.

38. Propagation of Varieties, Testing, Storage and Diseases.

The Station has been very fortunate in retaining the interest of Mrs. Moore (formerly Miss Joyce Hamond) and the part time services of Mr. Witt, head of the Propagation Section prior to his retirement, thus enabling these experiments to be continued on a modest scale.

Propagation. This work is now limited mainly to two lines of investigation: (*a*) Methods of layering species and varieties of *Juglans* are being tested in an attempt to produce clonal races of rootstocks for experimental purposes. Whilst the hybrids known as " Paradox " and " Royal " again rooted very well in 1936, varieties of *J. regia* and *J. nigra* gave comparatively few rooted layers. The species *J. Mandschurica* rooted fairly well, whilst *J. sieboldiana*, which incidentally is commonly used as a seedling rootstock by a well-known French nurseryman, rooted very well.

(*b*) Buds of the previous season's growth are being used for budding experiments out of doors. The best results have been obtained by inserting these in May and June,

although buds inserted as late as early August have succeeded. It appears that success in this method is likely to depend largely on seasonal conditions, sunshine and warmth. The cold wet season of 1936 was therefore not propitious.

There is still a big demand for grafted trees true to name, but most of the work of supplying the public was handed over to interested commercial nurserymen three years ago. Several firms have made a start in propagating clonal material under glass on the lines suggested by this institute but two facts militate against the rapid production of saleable young walnut trees. There is a very definite shortage of suitable grafting wood of the varieties recommended. The establishment of " stock " trees especially to supply grafts seems the only sound policy. Again, young walnut trees are slow growing in the first few years, and, whether rightly or wrongly, the public still expects a standard tree which after planting can more or less look after itself. Unfortunately a young walnut tree does not seem readily to stand the competition of other trees for light, air and moisture met with in ordinary woodland or coppice. This sort of competition is certainly not suitable for the small trees which are the only ones at present available for distribution. On the other hand, they appear to transplant more readily at this age. Since the demand resulting from the ever increasing interest far exceeds the immediate supply, preparations have been made once again to raise a limited supply of selected varieties by grafting under glass, in 1937. These will be distributed in consultation with the nurserymen interested.

Selecting and Testing Varieties. The walnut grove at the Station, containing some 120 trees of sixty varieties, affords very valuable material on which to continue observations upon time of leafing out in relation to frost injury and upon the formation of staminate and pistillate flowers in relation to pollination. Few of these young trees have yet produced any quantity of nuts.

The cropping of walnuts in 1936 was generally very erratic and many named varieties from the Continent such as Meylanaise, failed to develop fully and ripen their shells, probably owing to the lack of sunshine in September.

On the other hand, several native seedlings were inspected which had produced promising nuts with well ripened shells. In some cases these trees appear worthy of propagation and trial but they will receive a severe comparative test at the Station before they are added to the original twelve varieties selected for distribution. A very high standard must be maintained if nuts of native origin are to hold their own with the excellent samples from the Continent and America on the open market. Besides, it would be disadvantageous to multiply the number of varieties unnecessarily. The Station is always glad to have new seedlings brought to its notice from which to make drastic selection.

A very interesting avenue of twenty-one seedling walnuts about 45 years old was inspected at Faversham and afforded a very excellent example of the value of planting only selected varieties. While all the trees carried some crop, three trees were outstanding and bore from 500-700 lb. of husked nuts per tree. As it was, the owner said that this was his best paying crop in 1936. If the other eighteen trees had been equally good seedlings, there seems no reason then why walnuts should not prove a commercia crop even in an unpropitious summer.

An attempt is still being made, by the circulation of questionnaires, to keep in touch with the performance both of the selected seedling parent trees, which incidentally have now all been named with the consent of their owners, and also of the main sets of experimental named varieties which were distributed as widely as possible. Periodical visits would be much more satisfactory, if facilities allowed. (A.W.W.)

HOPS.

39A. Testing and Distribution of New Seedlings.

Twenty-four new varieties have been planted out for preliminary trial in place of a similar number that have been grubbed. The crop from each of over 250 seedlings was dried separately for cropping records and each crop from twenty-six varieties was pressed separately in part pockets for use in brewing tests. Samples of the dried hops, for the estimation of the preservative value, were taken from 116 varieties.

The analysis of the 1935 crop proved the seedling BB28 (which was analysed for the first time) to be the richest mid-season hop with a preservative value 13·74 per cent.

Among the late varieties 411 was the richest, being slightly richer than " Brewer's Gold " (C9a). Four new varieties, BB28, 411, " Brewer's Gold " and R3/100 exceeded in preservative value the richest American hops.

This work has been carried out in collaboration with Professor E. S. Salmon, who has published a report, and Mr. A. H. Burgess of the South-Eastern Agricultural College who has been responsible for the analyses.

The seedling OO63 which has proved satisfactory over a number of years has been introduced into commercial cultivation.

Another promising seedling Z62 has been named " Fillpocket " and is being planted up on a larger scale at East Malling to provide sets for growers.

39B. Cultural Trials.

The trial of various planting distances and numbers of bines per string on the seedling L21 has been concluded and a report on the results of the six years' work is in preparation.

Cultural trials with " Brewer's Favourite ", OV7 and Fuggles have been continued, but possibly owing to the exceptional weather conditions no significant differences in cropping have been recorded this season, except in the Fuggles trial. One strain of Fuggles again gave a heavier crop than the other two strains being tested. A half acre plot of the " " Quality Hop " (OO63) has been utilized for a " uniformity " trial this season. Sufficient material is now available to enable about half an acre to be planted up with the seedling OI47 for use in further trials.

HORTICULTURAL METEOROLOGY.

40. Phenological and Meteorological Records.

(a) Routine Meteorological Records.

Since the Agricultural and Meteorological Schemes of the Ministry of Agriculture and the Air Ministry was started in 1925, this work has undergone considerable development and modification.

The intensity of solar radiation is now being recorded with a Callendar Electrical Recorder, transferred from Cambridge University.

Although the Horticultural Observation Plot has been discontinued, extensive observations are still being made under the Phenological Scheme with the object of linking up such records as the time of leafing and blossoming, of certain plants, with meteorological phenomena.

With the development of other lines of work on the Station, these meteorological records are being found of increasing value to other sections on the Station.

Summaries of the weather conditions of the year 1935 have been published (H.27). (H.C.C. and H.M.T.)

(*b*) *Meteorological Records on Nursery Plot.*

For the third year the nursery plot designed to study the relationship between Meteorological conditions and Incompatibility has been carried on (see under Pomology, 8). (T.N.H. and R.J.G.)

(*c*) *Micro-climatology.*

During the year the question of setting out a proper plot of fruit trees and bushes for the study of micro-climatological conditions has been very fully discussed and a programme drawn up for reconsideration at a future date. (T.N.H. and R.G.H.)

(*d*) *The Technique for studying Katabatic Winds and Air Temperatures.*

As a result of the Conference on Frost Damage held at the Station on 11th September, 1935, the Ministry of Agriculture gave a provisional grant in January, 1936, to enable the Station to carry out preliminary climatological investigations.

It was decided that it was essential to begin these investigations by studying air currents and cold air drainage in relation to frost damage to fruit trees, especially during their blossoming period.

Since it is suspected that the irregular nature of the distribution of frost damage is connected with the presence of katabatic winds, a study of the latter has been begun. Up to the present only katabatic winds existing on wind-facing slopes have been investigated. Under these conditions the ordinary wind in the upper air is found blowing uphill on the upper part of the slope, and the katabatic is found blowing downhill on the lower part of the slope. Between these two winds blowing in opposite directions there is an area where the air is " calm ".

It seems possible that a knowledge of these katabatic winds and phenomena associated with them will enable one to explain the presence of areas where there is a danger of frost damage, and to suggest methods of removing that danger.

The variation and fluctuation in air temperature occurring on frosty nights on a one-acre plot of orchard were investigated. The variations included those that occur simultaneously at a given height above the soil, and were found to be of the order of 1° F., and the fluctuations mentioned are those that normally occur as the night proceeds. It was found essential to use shielded aspirated thermometers for this work in order to record the air temperature with the required accuracy.

This work is being followed up by an investigation into the minimum temperatures occurring at various points over an area of several square miles.

This work on air temperatures, important though it is, leaves untouched the problems associated with the relationship between the air temperature and the temperature of fruit buds. The latter temperature is of especial importance to fruit growers.

In the course of this work simple apparatus has been designed both for taking air temperatures in the orchard and for measuring the speed and direction of winds of low velocity. Various means of making the movements of the air currents visible, such as a hanging thread, released thistle-down, and white " cold " smoke have been the subject of experiment.

Opportunity was also afforded to make a preliminary study of the technique of orchard heating experiments. Although from this point of view the season was unfavourable, certain valuable information was obtained regarding the technique of air temperature measurement, the location, and lay-out of such experiments.

In the light of the information gained from the experience with orchard heaters, and from the study of minimum-temperature patterns and katabatic winds, it seems that it may be possible to define the limits of the areas within which orchard heaters are likely to prove successful. (C.E.C.)

In Relation to Small Fruit.

CLASSIFICATION, NOMENCLATURE AND VARIETIES.

41. Black Currants.

The yields of Black Currants were again reduced by frosts during blossoming. The variety that was least affected was Goliath.

In the five-year-old trial of Baldwin at 5 ft. × 6 ft. and Triple X at 7 ft. × 6 ft., the former again gave the heavier yield per bush. In the younger trial of Boskoop, Baldwin, Seabrook and Goliath planted at varying distances, Goliath gave the heaviest weights per bush. It was followed by Baldwin, Seabrook and Boskoop all of which were more damaged by frost.

41. Red Currants.

In the Red Currant variety trials the latest variety to flower, i.e. Wilson's Longbunch, was the only variety that was not damaged by frost and in consequence it set a full crop.

A preliminary test of methods of tying in the young shoots and of shortening back others, to prevent blowing out by winds, was carried out. As no strong winds were experienced no damage occurred in any of the treatments, including the controls. The treatments will be repeated over a number of seasons. (J.A.)

42. Raspberries.

See under IX.

43. Loganberries, Blackberries and Dewberries.

See under XI.

44. Strawberries.

See under X.

BREEDING.

45. Black Currants.

A number of Black Currant seedlings selected in 1933 as showing outstanding promise have now been propagated in quantity and are being planted out for a comparative cropping trial. A further season's observations have been made on the series of crosses between the main varieties raised in 1930. A number of promising selections have been made which will be propagated for further trial.

Close study during the past season has failed to detect any abnormalities in the large series of selfs and crosses between Baldwin and Boskoop Giant, the parent bushes of which had their pollen, ovules and seeds subjected to X-ray treatment at the John Innes Horticultural Institution in 1932. A further generation will be raised from this material during the spring of 1937. Interspecific hybrids between the Black Currant and *Ribes longeracemosum* have again proved completely sterile. (H.M.T.)

46. Red Currants.
This work is temporarily in abeyance.

47. Raspberries.
See under IX.

48. Strawberries.
See under X.

PROPAGATION.

49. Currants.
A clonal disease-free nucleus is being maintained.

50. Raspberries.
See under IX.

51. Gooseberries.
Clonal dessert varieties are being maintained.

52. Strawberries.
See under X.

53. Loganberries and Blackberries.
See under XI.

PLANTING, TRAINING, PRUNING, THINNING.

54. Currants.
Suitable distances and pruning treatments are being tested (see 41 above). (R.G.H. and J.A.)

55. Raspberries.
See under IX.

56. Gooseberries.
Fruit thinning trials are continued as opportunity permits. (A.C.P. and B.L.W.)

57. Strawberries.

See under X.

58. Loganberries and Blackberries.

See under XI.

MANURING.

59. Raspberries.

See under IX.

60. Strawberries.

See under X.

PUBLICATIONS DURING THE YEAR.

Bagenal, N. B. "Fruit Growing as a Career." Manchester Evening News, 13th January, 1936. (E109.)

Summary.

A short popular article describing the best methods of obtaining a training in commercial fruit growing, with hints on what to look for in selecting a site, and in planting the trees.

Bagenal, N. B. and Turner, A. D. "Dwarf Pyramid Apple Culture at Cannington." Scientific Hort. (March, 1936). **4,** 67-74. (E107.)

Summary.

An account of the demonstration and experimental plot of dwarf pyramid apple trees planted at the Somerset Farm Institute, Cannington, in 1929 and 1930. Shaping, pruning, soil treatment and manuring are described in their relation to tree performance and to each other.

Rogers, W. S., Kent, W. G., and Pearl, R. T. "The R.H.S. Conference on Cherries and Soft Fruits, 1935." Scientific Hort. (March, 1936). **4,** 79-89. (E97.)

Summary.

A review is given of the main points raised in papers and discussions on the following subjects: Strawberry cultivation, propagation, pests and diseases; growing healthy raspberries; the nutrition and manuring of soft fruits; varieties of blackberries and allied fruits; and cherries for market growing purposes.

Bane, W. A. "Investigations on Frost Damage to Horticultural Crops, with suggestions for future work." Journ. Min. Agric. (March, 1936). **42,** 1212-18, and E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 220-4. (E98.)

Hoblyn, T. N., Grubb, N. H., Painter, A. C., and Wates, B. L. "Studies in Biennial Bearing. I." Journ. Pom. and Hort. Sci. (April, 1936). **14**, 39-76. (E99.)

Summary.

Part I.

1. An arithmetical method of evaluating the degree to which trees show the biennial habit is described.

2. The trees' history in this respect is shown by two constants. For any particular period, the constant " B " is calculated to show whether the tree is wholly, partially, or not at all biennial; and the violence of its fluctuations is shown by the Intensity (" I "), calculated from the differences between consecutive pairs of years.

3. The importance of fruit bud formation and its relation to fruit set, in any study of regularity of bearing, is stressed.

Part II.

The application of the method described in Part I to the fruit records from the Apple Pruning Plot shows that either " B " or intensity or both may be affected by :

1. The variety. Current ideas of the behaviour of different varieties are in the main confirmed.

2. Root competition from a poplar windbreak.

3. Drastic pruning of formerly " unpruned " trees.

4. A difference in the pruning treatment in the " on " and " off " years. Drastic spur-shortening early in the " off " year reduced biennial intensity compared with similar treatment early in the " on " year.

5. Applications of potash manures. Here results in opposite directions with different varieties were confirmed by changes in treatment.

6. Grassing-down, and subsequently feeding with nitro-chalk. Only one out of six varieties was clearly affected.

The causes of fluctuations in biennial intensity are discussed.

Part III. Attempts at Control.

1. Stripping of the blossom from whole trees of Early Victoria completely changed the year of cropping and increased biennial intensity; thinning had no effect.

2. Stripping the blossom of certain branches or parts of trees gave results differing with different varieties. Usually the year of cropping of the stripped parts was changed.

3. Comparison of stripped and untreated branches with whole trees stripped or untreated shows a lower and falling biennial intensity for the former. Differences between partly treated trees could be accounted for by the varying proportion of the whole tree's blossom removed.

4. Results as a whole strongly suggest that differently treated branches of the same tree did not behave independently.

5. No difference was discernible in the results obtained from early and late stripping of the blossom.

6. No result was obtained from blossom thinning.

7. In an experiment carried out on young trees of Upton Pyne and Laxton's Superb, the complete removal of fruit each year clearly overcame the biennial habit.

Heavy thinning certainly reduced biennial intensity, but the effect of light thinning, though in the same direction, was not significant.

TYDEMAN, H. M. " Variation in the ' Paradise ' Apple Rootstocks. A Study of some Leaf and Shoot Characters in Four Races." Journ. Pom. and Hort. Sci. (April, 1936). **14,** 19-25. (E100.)

SUMMARY.

This paper summarizes the results of a study made upon the shoots arising from the stools of two races, the original grouped collections of botanically similar rootstocks and re-selected clones raised from a single individual of " Paradise " apple rootstocks, Malling Nos. II and IX.

The characters studied were leaf shape (the length × breadth relation and the distance from the leaf apex to the point of maximum breadth), the length of the leaf stalk, number of serrations around the leaf margin, the length of the stipules, taper of the leaf apex and the number of lenticels in the wood. While it was made clear that the data presented were not adequate to give a complete picture of the variation within these races, the results obtained confirm the view that neither the amount of variation nor the expression of the characters is appreciably different in the two races of either of the rootstocks.

BEAKBANE, A. B. and RENWICK, M. E. " A Preliminary Report on the Internal Structure of the Wood of No. IX Rootstock in relation to Scion-rooting of apples." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 100-6. (E101.)

AMOS, J., HOBLYN, T. N., GARNER, R. J., and WITT, A. W. " Studies in Incompatibility of Stock and Scion. I. Information accumulated during twenty years of testing fruit tree rootstocks with various scion varieties at East Malling." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 81-99. (E102.)

PAINTER, A. C. " Some Notes on one Year's Experience with a Gas Store." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 213-19. (E103.)

TYDEMAN, H. M. " The Root Systems of some Three-year-old Trees of Lane's Prince Albert on Two Selected Rootstocks (Northern Spy × Malling No. II)." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 107-10. (E104.)

HAMOND, J. B. " Results of Walnut Research." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 228-31. (E105.)

ROGERS, W. S. " Some Observations on the Roots of Fruit Trees." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 210-12. (E106.)

GARNER, R. J. " The Rapid Conversion of Unprofitable Fruit Trees by Grafting." Berkshire Farmer's Year Book, 1936, and E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 204-9. (E911.)

ROGERS, W. S. " The Relation of Soil Moisture to Plant Growth, illustrated by Moisture Meter Experiments with Strawberries." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 111-20. (P1.)

FEILDEN, G. St. C. and GARNER, R. J. "Vegetative Propagation of Tropical and Sub-Tropical Fruits." Imp. Bur. Fr. Prod. Tech. Comm. No. 7. 1936. (E113.)

SUMMARY.

Illustrated descriptions of different methods of vegetative propagation are given. The particular methods recommended or known to be used in the propagation of ninety-nine individual tropical and sub-tropical fruit varieties are detailed. An index of popular and botanical names makes for easy reference.

HATTON, R. G. "Plum Rootstock Studies. Their Effect on the Vigour and Cropping of the Scion Varieties." Journ. Pom. and Hort. Sci. (July, 1936). **14,** 97-136. (E110.)

SUMMARY.

1. The position with regard to varieties of rootstock, their methods of propagation, present use, is summarized.

2. A small investigation of the comparative behaviour of a clonal rootstock raised by different vegetative methods is reported.

3. Data from trees growing on different clonal races of Myrobolan and St. Julien are presented to illustrate the degree of variability resulting.

4. Three field trials comparing the growth and cropping of certain representative and local plums on their own roots and budded upon foreign rootstocks are described. At present trees on Myrobolan are growing more vigorously than the same varieties on their own roots—Victoria is an exception and propagates readily from layers.

The trees have cropped as well on their own roots as on Common Mussel or Common Plum stocks.

5. The measurements of vigour and weight of crop from three successional plantings embracing fourteen varieties and eight principal rootstocks—from eleven to fourteen years old—are presented and discussed.

Considerable differences in vigour as expressed in cross-section of stem and total weight of tree are demonstrated and proved significant. Similar comparisons are given in relation to total crop and earliness of coming into bearing.

6. Size of tree in relation to distance of planting and crop per acre is discussed.

7. Nearly all varieties on Myrobolan are the most vigorous. Trees on Common Plum, Brussels and Common Mussel are usually partially dwarfed.

In relation to size of tree, the crops from Yellow Egg stock and Marianna are frequently outstanding.

8. Some influences of rootstock on time of ripening and size of fruit are illustrated.

9. The value of certain local rootstocks is tested in comparison with better known stocks.

10. The relationship of variety and rootstock to death from Silver Leaf, Bacterial Dieback and Delayed Incompatibility is reviewed.

11. The development of sucker growths from the roots is shown to be chiefly dependent upon the rootstock but also influenced by scion variety.

12. The general trend of the results is discussed and practical suggestions made to the fruit grower.

GRUBB, N. H. "Varieties of Cherries." Herefordshire County Council Agric. Quarterly Journ. (September, 1936). **4**, 119-23. (E112.)

SUMMARY.

This article gives preliminary results of the work on cherry varieties begun at East Malling in 1920. The number of distinct varieties in the East Malling collection is estimated at over 150, allowance being made for some confusion in nomenclature, of which instances are given.

Local varieties, apparently distinct from those grown elsewhere, have been found in every county where cherries are widely grown.

The chief requirements for a good commercial variety are discussed, and special attention is paid to those varieties which have proved at East Malling to be most resistant to various diseases.

The article concludes with a few words about cropping and fruit quality.

HEARMAN, J. "Northern Spy as a Rootstock when compared with other Standardized European Rootstocks." Journ. Pom. and Hort. Sci. (October, 1936). **14**, 246-75. (E111.)

SUMMARY.

1. A survey of literature is made.

2. The root habit of Northern Spy apple was investigated by detailed excavation of the root-systems of a number of young Northern Spy trees ranging from two to six years old, a section of a seventeen-year-old tree, and also a complete fifteen-year-old tree of Grenadier on Northern Spy rootstock. Young trees of Ivory's Double Vigour and Malling Stocks Nos. I, II, IX and IV were excavated for comparison. In all, forty-seven trees were excavated. Comparisons were also available with the root-systems of older apple trees of other varieties previously excavated from the same soil type.

3. A description of the excavation technique is given.

4. Variation in the type of root and top growth among a collection of plants sent from New Zealand is noted. Two distinct types are illustrated.

5. Four-year-old trees of Northern Spy excavated from nursery rows showed considerably less vigour both of root and branch than comparable trees of Ivory's Double Vigour. The roots of the latter had a more marked downward tendency than those of the former, though the deepest root found in this series was a Northern Spy root.

6. In a plot of nine clonal layers each of Northern Spy and Stocks I and IV, only four Northern Spys remained alive after one dry summer though all the other stocks grew well. This illustrates the poor power of recovery of Northern Spy after transplanting—a fact noted throughout the investigation. This plot was widely spaced to avoid root competition.

Two years after planting, three trees each of Nos. I and IV, and the two best Northern Spys were excavated. Distinctive root characteristics were found. The root-systems of the Northern Spys were weak, sparse, one-sided, and poorly developed, with little fibre.

The No. I roots occupied just over a square metre of soil. There was much fibre round the collar of the tree and many roots extending to a depth of 60-110 cm. The

No. IV trees showed most vigour. Their mean root spread was nearly two metres. On the whole their roots were shallower than those of No. I, and about half of the deep roots occurred near the periphery of the root-system.

7. Six Northern Spy trees six years old were excavated and compared with six trees of No. II, five years old. Both sets of trees had been stringfellowed (i.e. all roots were removed) and replanted two years previously. Root weights were obtained in various soil regions for two trees of each set. The trees of No. II were less than twice as heavy as those of Spy at the time of planting, but they produced more than three times as much root as the Spy trees in the two years preceding excavation. This is another measure of the relatively slow recovery power of Spy. The ratio of new root weight to new stem weight was similar in both Spy and No. II.

The percentage of total root weight at more than 34 cm. deep was 8·1 for Northern Spy and 8·0 for No. II.

The No. II root-systems spread in all directions. Roots penetrated downwards as well as outwards from the trunk. The Spy root-systems remained nearer the surface near the trunk, but some roots turned downwards near the periphery of the root-system.

The whole series of excavations gives the impression that the root-system of Spy, developing unhampered by outside root competition, forms a shape rather like a tin lid. The main scaffolding appears to be shallow, and such deep roots as are formed occur near the extremities.

The root-systems of Stocks Nos. I and II, and Ivory's Double Vigour, however, in the first two years, appear to spread evenly in all directions from the trunk, thus filling a volume of soil like half a ball, cut at the soil surface. No. IV approaches the Spy formation, though not in so marked a degree. These characteristics are modified by soil factors and root competition.

8. A seventeen-year-old Spy tree partly excavated had roots descending to 260 cm. Some of these were directly below the trunk (although no " tap roots " were found in any of these excavations). It is thought that this departure from the habit noted in younger trees is due to severe root competition from an adjacent poplar hedge.

A marked development of aerenchyma tissue, not reported on other rootstocks, was found on the deep Northern Spy roots. This may be an indication that the Northern Spy roots are not well adapted to deep and less well aerated soil regions.

9. The complete excavation of a fifteen-year-old Grenadier on Northern Spy rootstock, growing in a plantation between other trees on various rootstocks of differing vigour, showed clearly both the weak uneven growth habit of Northern Spy, and the effect of root competition.

On the side next to a small tree on a very dwarfing stock, the Spy root-system spread more than three metres from the trunk, mainly at a depth of less than 30 cm. but sending down vertical roots in the region where roots from the other tree were growing.

On the opposite side, the roots of a tree on a vigorous rootstock approached quite close to the Northern Spy. Here the Spy roots grew much deeper—apparently through the competition of the other roots. The deep roots were not vigorous, however, and were found to be connected with the weaker side of the very one-sided branch system. This latter point was proved by a dye injection technique.

10. In general, it appears that Northern Spy has a very distinctive natural root habit, and is not able to adapt itself to uncongenial surroundings.

SALMON, E. S. "Nineteenth Report on the Trial of New Varieties of Hops, 1935." (August, 1936.) (B27.)

SUMMARY.

1. Of the 174 varieties (new and commercial) tested, three new varieties cropped at the rate of 30 cwt., or over, to the acre, fourteen other new varieties at 25 cwt. or over, and thirty-six new varieties at from 20 to 24¼ cwt. to the acre.

2. The number of bushels (Imperial) of green hops required to the cwt. of dried hops varied from 70 to 139.

3. Fifty-two of the new varieties proved on analysis to be richer in preservative qualities than the richest sample of Golding hops grown at Wye (Early Birds, 9·70 per cent.).

4. Of nine samples of the richest American hops obtainable, one sample of Sonomas was richer by 0·33 per cent. than the richest new variety, 411. The remaining samples were all beaten by the new varieties 411 and C9a ("Brewer's Gold").

5. Notes are given on certain new varieties which are being grown commercially or which show commercial promise.

6. A number of new varieties, suitable for cultivation in this country, are equal or superior in preservative qualities to the imported American hops.

II. STATISTICS AND RECORDS

61. Records.

The routine work of filing and summarizing records has occupied much of the section's time, although on account of the extremely light fruit crop in 1935, there has been more work done on bringing summaries and other records up to date, and testing new methods of sampling.

Analysing the records statistically has become the more important part of the work of the section. All the more recently planned trials have been designed to test the maximum number of comparisons for the number of trees planted or amount of land utilized ; in consequence the analysing of the records is necessarily more complex than it was in the days of the extremely simple stock trials. In this connection recently developed methods of analysis are being used, such as the analysis of co-variance, by means of which one is able to eliminate the original size of the tree from the differences in growth caused by manurial or other treatments. This has been used in analysing the Cox and Beauty of Bath manurial trial.

Material for papers on plum and pear rootstock trials has been prepared, and a paper on biennial bearing (E99) has been published in collaboration with other sections. (T.N.H. and J.L.E.)

62. Technique of Recording.

In 1936 the fruit crop was extremely heavy for all kinds of fruit. In the case of apples and pears, where number of fruits and weight of fruits are recorded separately, help was given to the recording staff by checking these two records against each other before the fruit was removed from the plot, when a mistake in counting or weighing could be easily seen and corrected. (T.N.H. and J.L.E.)

A further experiment in sampling technique for size and colour of apples has been carried out with Allington Pippin. (J.L.E.)

63. Plot Lay-out.

Several small experiments have been planned. Further analyses have been made on the strawberry uniformity trial material, and a report on this will be published shortly.

See also Horticultural Meteorology 40 (*b*) and (*c*).

PUBLICATIONS DURING THE YEAR.

Hoblyn, T. N. " Spring Frosts at East Malling 1915-35." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 124-30. (H28.)

Hoblyn, T. N., Grubb, N. H., Painter, A. C., and Wates, B. L. " Studies in Biennial Bearing. I." Journ. Pom. and Hort. Sci. (April, 1936). **14,** 39-76. (E99.) (For Summary, see page 50.)

Chapelow, H. C. and Tydeman, H. M. " Weather Conditions during 1935." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 121-3. (H27.)

III. PLANT PHYSIOLOGY

64. Analysis of Growth Relations of Stock and Scion.

(*a*) *Relative Parts Played by Roots and Stem in Stock Influence.*

During 1936 a new series of trees were worked in which the rootstocks No. IX and No. XII have been combined as scion, intermediate and stock in all possible ways, i.e. IX/IX/IX, IX/IX/XII, IX/XII/IX, IX/XII/XII, XII/IX/IX, XII/IX/XII, XII/XII/IX and XII/XII/XII. Two different lengths of intermediate are being tried and unworked trees of both stocks are being included for comparison. These trees will be planted out in latin squares in the winter of 1937, when they will have completed their maiden year in the nursery. It is hoped that this experiment may throw light on the relative importance of the roots, stock stem and the graft union in stock effect on tree performance.

Observations are being continued on the two older series of trees in which the scion variety Stirling Castle has been combined with root systems of stocks and intermediate pieces of stem of the same or different stocks. (H.L.P.)

(*b*) *Time, Nature and Distribution of Summer Growth.*

Methods for analysis and interpretation of data obtained by the " census " method for recording summer growth are being worked out and prepared for publication. This method is also being used as a matter of routine in other investigations such as that on biennial bearing (see (*h*) below). (M.C.V.)

(*c*) *Seasonal Course of Root and Shoot Development.*

Further samples of the trees of the two scion varieties, Cox and Lane, each on the four rootstocks, I, II, IX and XII, have been dug up during 1936 and analysed morphologically to determine the effect of scion and stock on the total, and the relative amounts of leaf, stem and root. This experiment will be finished in the autumn of 1936.

A further experiment on the same general lines has been begun in 1936. Here stock varieties have been used to provide the shoot system or scion as well as the root-system. The trees were worked in the summer of 1936 and consist of all possible combinations of the three rootstocks, Nos. IV, IX and XII, i.e. IV/IV, IV/IX, IV/XII, IX/IV, IX/IX, IX/XII, XII/IV, XII/IX and XII/XII. The weights of the individual stocks were taken before planting, and a sample was lifted at the time of budding to determine the amount and distribution of growth up to that time. Further samples will be taken from the nursery rows during the maiden year, to determine the course of the re-establishment of the normal stem/root ratio after " snagging ". The trees will then be transplanted from the nursery rows and samples will be lifted and cut up over several seasons. The main object of the experiment is to determine the relative effect of a stock variety when used as (*a*) a root system, (*b*) a shoot system on the total amounts and the proportions of leaves, stems and roots and to find out whether it would be possible to foretell what effect a variety would have if used as a stock, by observing its effect when used as a scion. (M.C.V.)

(*d*) *Cambial Activity at the Union.*

Work on this is now being carried out in the Pomology Section (see 8).

(*e*) *The Assimilation Rates of Apple Leaves.*

Owing to the pressure of other work this investigation has been discontinued for the present. (H.L.P.)

(*f*) *Seasonal Absorption of Nutrient Salts by Apple Trees grown in Water Culture.*

Preliminary work has been carried out on a technique for growing apple trees in water culture. When the roots were completely immersed in the culture solution, the trees made excellent growth, provided the solution was aerated efficiently; in some cases they increased threefold in fresh weight in a single season. They suffered, however, from iron deficiency, even though iron was supplied in the form of ferric citrate. This deficiency was cured by standing the trees with their roots in a solution of ferric citrate alone for twenty-four hours once a fortnight. The root-systems, however, practically ceased growth towards the end of the season. When the roots were not immersed in the solution but were kept constantly sprayed with it by a method similar to that described by Professor Barker (Long Ashton Report 1921) the trees made slightly less growth but root growth continued later in the season, and the trees did not suffer from iron deficiency. There were indications that aeration is more necessary for some stocks than for others, and this may help to explain variations in the performance of certain stocks on different soils. A short account of this preliminary work appears in this Report, p. 131.

An experiment including trees of four different stocks is being begun; and the residual solutions will be analysed at intervals to determine whether the different types of tree absorb the nutrients in different proportions. (H.L.P., W.A.R. and M.C.V.)

(*g*) *Water Relations.*

Some work on this is being carried out in connection with the investigation (*c*) above. (M.C.V.)

(*h*) *Biennial Bearing.*

An intensive study is being carried out in collaboration with the Pomology (I.13) Biochemistry and the Fungicides and Insecticides Sections. The work includes:—

(i) *Morphological examination* and mapping of five varieties of apple to determine if there is any connection between the position, nature or "category" of a growth and its likelihood of becoming a fruit bud next season.

(ii) *Influence of manuring* and stock.

(iii) *Relation of leaf area* to fruit bud differentiation in the various "categories". This involved the measurement of 25,000 leaves.

(iv) *Chemical analysis* on samples of spurs and shoots from "on" and "off" year trees which have been collected before, at the time of, and after, the period of fruit bud formation.

(v) *Carbohydrate/Nitrogen Ratio.* Investigation of the hypothesis that the carbohydrate/nitrogen ratio plays an important part in bud differentiation by supplying these two substances to the trees at various times of the year as glucose and urea by the method of tree injection.

(vi) *Manipulative Treatments* aimed at breaking the biennial rhythm. These include complete and partial deblossoming and defruiting of " on " year trees and various degrees of defoliation of " off " year trees. The use of certain sprays and chemicals for effecting deblossoming has been tried with some success. In addition injection of various nutrients has been tried with the idea of changing the balance of nutrient materials within the tree. (M.C.V.)

(vii) *Embryo Development.* Some observations on the period of embryo development in apples were made as a side issue of the nutrition problem, and a short account is given in this report. (P.K.S.)

(i) Effect of Deblossoming and Degree of Pruning on Growth.

An experiment planned in collaboration with the Statistical Section was started in the spring of 1936. It consists of trees of two scions, Cox and Worcester, each on two stocks, IX and XII. The treatments are three degrees of pruning: hard, light and none. Some trees under each treatment will be completely deblossomed, the rest will be allowed to fruit. Originally there were two series of trees, one planted with the normal amount of root, the other derooted, but the latter suffered severely during the dry spell in May and June and will be replaced by a new series with the normal amount of root. Full records will be taken on these trees for several years and they will then be dug up and weighed. (M.C.V.)

65. Vegetative Propagation (in collaboration with Propagation).

Hardwood Cuttings.

The routine experiments on the effect of a substratum of humus below the sand are being continued.

The experiments on the effect of the presence or absence of leaves at the time of planting, on the time of planting and the effect of shade have been repeated.

A rather complicated experiment to test the effect and combined effect of several treatments has been started. The treatments include protection by garden lights, " photoperiodism " or artificial shortening of period of daily illumination, and the use of growth promoting substances. (R.J.G., M.C.V. and H.L.P.)

Layers.

Effect of growth promoting substances on rooting is being tried. (See below.) (R.J.G. and H.L.P.)

The Effect of Chemical " Growth Substances ".

One of the objects of this work is to find out if the rooting of cuttings and layers of various species of apple, plum, etc., which are either difficult to root or which require long periods to form roots can be encouraged by the use of synthetic growth substances.

Preliminary work to test methods of application and other matters of technique have been carried out on young tomato plants as these plants are known to respond readily to these substances. A new method of applying the substances dissolved in water in the form of a spray, has been tried with some success; by it the amount and distribution of the substance applied can be more accurately controlled than by the methods formerly described by other workers.

A note on this method and on the results of spraying tomato plants with phenylacetic acid has been published in *Nature* (F21). The results of a daily spraying with a 0·1 per cent. solution for one week include :

(1) A 30 per cent. increase in the height of the plants.

(2) An increase in the lengths of internodes and leaf stalks.

(3) Very significant alterations in the relative dry weights of leaves, leaf stalks, stems and roots ; those for leaf and root being depressed whilst those for leaf-stalk and stem were increased.

(4) Increase in the water content.

(5) Initiation of roots on the stems when the plants were kept under humid conditions.

A paper has been prepared for publication on the effects on the growth of tomato plants of spraying with phenylacetic acid, and indolebutyric acid. In addition to the results cited above continued spraying with either of these substances caused total inhibition of the terminal bud after three weeks' treatment. Indolebutyric acid also caused increased root growth. The effect of the concentration of the solution applied is also discussed.

When apple shoots growing in the open were sprayed with the growth substances they reacted very quickly as shown by the characteristic downward curvature of their leaves. Shoots in active growth responded most readily.

These substances will also be used in experiments on cuttings and layers with the object of determining (*a*) the best method of application, (*b*) the appropriate concentration to use, (*c*) and the most favourable time of the year to promote the maximum rooting response. (H.L.P.)

PUBLICATIONS DURING THE YEAR.

Vyvyan, M. C. " A Note on the Moisture Content of the Stems of Different Rootstocks." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 131-3. (F19.)

Pearse, H. L. " Effect of Phenylacetic Acid on the Growth of Tomato Plants." Nature (August, 1936). **138,** 363-4. (F21.)

Summary.

1. A method of applying phenylacetic acid to the aerial parts of the plants by spraying is described.

2. Epinasty of the leaves, proliferations on the stems and petioles, and initiation of roots were obtained by the spray method of application, results similar to those obtained by other workers using the substances dissolved in lanolin and applied locally or added as a water solution to the soil.

3. A daily spraying for one week with a 0·1 per cent. solution of phenylacetic acid increased growth in height and increased the lengths of the internodes and petioles.

4. In addition it induced differential responses in various parts of the plants ; leaf and root growth was reduced while stem and petiole growth was increased.

5. The growth of the apical bud was gradually inhibited.

6. The water content of the plants was increased.

IV. BIOCHEMISTRY

MUTUAL INFLUENCE OF ROOTSTOCK AND SCION.

66. Elementary Analysis.

Work has progressed along the lines indicated in previous reports.

(i) Polarographic. Mr. Marsden of the Imperial College of Science, London, with the help of the physics workshop of the College has rebuilt the polarograph ; but pressure of other work has up to the present prevented him from using it for analytical work.

(ii) Spectrographic. Mr. A. L. Tackley has worked on this problem during the months October to December. Methods for preparing and sparking the electrodes have been improved. There is hope that it may be possible to do a complete quantitative mineral analysis on one centigramme of air-dried plant material. (W.A.R.)

67. Organic Analysis.

No work has been possible. (W.A.R.)

68. Plant Injection.

Distribution.

A paper describing in detail the various types of injection is nearly ready for publication (see also K15). (W.A.R.)

Avoidance of Damage.

The delay in the appearance of leaf damage due to the injection of an overdose of nutrient reported last year (K14) was noticed again, but in lesser degree, early this season, when there was a frost soon after bud-break, indicating that extra caution must be exercised when injecting trees after a late frost. (B.F.G.L. and W.A.R.)

Results of Injection.

(i) Artificial Manures. The injection of individual branches of pear trees with a solution containing 0·25 per cent. urea and 0·25 per cent. dipotassium hydrogen phosphate was followed by a marked increase in growth (see also I, Pomology). (D.N.S. and W.A.R.)

(ii) Iron salts for chlorosis. The results of diagnostic leaf injection suggest that iron metabolism is faulty in a large number of trees in the Research Station plantations.

The results of injections carried out at Teynham, Sittingbourne and Swanley and observations made elsewhere suggest that iron metabolism is faulty over wide areas of Kent.

Chlorosis in various fruits in various parts of Kent has responded to experimental :—

(1) Injection of iron salts (pears, apples at the Research Station, peaches and apples at Swanley, cherries at Sittingbourne and apples at Teynham).
(2) Driving of nails into the tree trunk at Sittingbourne.
(3) Application of humus (slightly) at Sittingbourne and Swanley.

Further similar experiments have been started elsewhere in collaboration with the Advisory Officers in Commercial Fruit Growing. (W.A.R. and B.F.G.L.)

(iii) Nitrogenous and Phosphatic Compounds. A preliminary report on the effect of injecting nitrogenous compounds has been published (K16). Apple trees have been injected with various compounds and Dr. A. C. Hulme of the Ditton Laboratory is examining the fruit by both chemical and physiological methods. Sodium phosphate alone had little effect on the respiration rate of the fruit and urea increased it greatly ; but the injection of sodium phosphate and urea together reduced the respiration rate to below even that of untreated fruit. These facts suggest that the poor keeping quality of apples grown on highly nitrogenous soil might be improved by the application of phosphatic manure. (B.F.G.L. and W.A.R.)

(iv) Nutrients and Disinfectants against Silver Leaf. Special trees are being raised for this work and a cheaper fungicide is being sought (see V, Plant Pathology, Mycology and Bacteriology, 72). (W.A.R. and H.W.)

(v) Insecticides against Woolly Aphis (see VI, Entomology, 82).

(vi) Molybdenum Compounds. Young Cox's Orange Pippin apple trees on XII and XVI treated with ammonium molybdate, both by injection and by application to the soil, were no more precocious in forming blossom buds than untreated trees.

(vii) Biennial bearing (see I, Pomology, 13 and III, Plant Physiology, 64*h*). Mineral nutrients and organic compounds such as sugars and urea have been injected so that their effect on biennial bearing may be studied.

(viii) Nutrient salts on Insect Pests. A systematic investigation has been started in collaboration with Dr. A. M. Massee. (B.F.G.L.)

(ix) Physiological Disorders (Bitter Pit, Water Core, etc.). The injection of trees bearing apples suffering from bitter pit with boric acid and other compounds did not lessen the trouble. Observations have been taken with a view to further experiments. (W.A.R., B.F.G.L. and H.H.)

WOOLLY APHIS.

See VI, Entomology, 82.

ABSORPTION OF NUTRIENT SALTS BY ROOTS.

See III, Plant Physiology, 64*f*.

BACTERIAL DISEASES OF FRUIT TREES (see V, Plant Pathology, Mycology and Bacteriology, 74).

Plot experiments have been started to test separately the effects of soil acidity and of availability of iron in the soil on resistance to canker (see C118). The effects of acidity of the cell sap and the availability of iron in it are being tested by injection. (W.A.R. and H.W.)

INARCHING TO IMPROVE TREES ON POOR ROOTSTOCKS.

See I, Pomology 1.

MULCHING.

The application of a straw mulch early in July around small trees had an effect on their growth. (W.A.R. and B.F.G.L.)

PUBLICATIONS DURING THE YEAR.

HEARMAN, J., LEVY, B. G., and ROACH, W. A. "Tree Injection. 1935 Experiments. A Progress Report." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 137-41. (K14.)

ROACH, W. A. "Leaf Injection." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 134-6. (K15.)

HULME, A. C. and ROACH, W. A. "Biochemical Studies in the Nitrogen Metabolism of the Apple Fruit. III. Preliminary Experiments on the Effect of Injecting Nitrogenous Compounds into Apple Trees on the Composition of the Fruit. (With an appendix describing a new Vacuum Extractor.)" Biochemical Journ. (August, 1936). **30,** 1397-1404. (K16.)

SUMMARY.

1. Two varieties of apple trees were injected in the summer of 1935 with solutions of ammonium nitrate, urea and asparagine.

2. The fruit, gathered in the autumn, from the injected trees contained greater amounts of total nitrogen than from the uninjected trees; the distribution within the total nitrogen was also different.

3. When detached from the tree and placed at 9·5°, fruit from trees injected with ammonium nitrate and with asparagine did not synthesize protein, whereas that from untreated trees synthesized considerable amounts of protein.

4. Further experiments are necessary to determine whether this difference in behaviour is a direct result of the injection or whether it is due to delayed ripening of the fruits from the injected trees.

V. PLANT PATHOLOGY, MYCOLOGY AND BACTERIOLOGY

PATHOLOGY OF TOP FRUITS.

70. Crown-gall.

Galls on hop, bramble and phlox have come under observation during the year. Organisms have been obtained from them for comparison with the crown-gall organism. (H.W.)

Trees have been examined which were used to test the value of organic mercurials applied to apple stocks at the time of planting as a protective against crown-gall, the number and size of the galls being recorded. Of three preparations tested, promising results were obtained with one of them, but it is proposed to repeat the experiment before drawing any definite conclusions as to the efficacy of the preparation. (H.W. and R.J.G.)

Relative Susceptibility of Apple Stocks.

Further series of growth records have been made on the trees in the experiment started in 1935 and referred to in the Report for that year. The complete results of the experiment will be available during the winter of 1936-7. (R.V.H.)

71. Brown Rot.

Further observations on the rotting of plums in cold storage have been made, and again it has been found that the wastage due to fungal infection is brought about mostly by *Sclerotinia fructigena*. (H.W. and A.C.P.)

For results of spraying trials against brown rot blossom wilt in Morello cherries, see under VII, Insecticides and Fungicides (96).

72. Silver Leaf.

(*a*) Observations have been continued on plum trees with Silver Leaf which had been injected with various nutritive and fungicidal substances to ascertain what effect such treatment has on the disease (see IV, Biochemistry, 68). (W.A.R. and H.W.)

(*b*) *A "Papery Bark Canker" of grafted apple trees.* Further evidence has been obtained regarding the connection of this disease and Silver Leaf. The fungus isolated from the wood of affected apple trees had the habit of *Stereum purpureum* in culture, and inoculations into plum trees have produced silvering of the foliage. (H.W. and R.J.G.)

An account of inoculation experiments on plum trees and field observations on a double-worked pear tree has been published (C121). The rapid infection and death of young plum trees after inoculation with *Stereum purpureum* is described ; the fungus extended throughout the stem and into the rootstock and roots during a period of about ten and a half months. An account is also given of a stem canker with " papery bark " as observed on a young double-worked pear tree infected with *Stereum purpureum*.

73. Influence of Stock on Scion.

In relation to disease, see 97.

74. Bacterial Diseases of Fruit Trees.

Bacterial Canker of Plum Trees.

Experiments designed to throw some light on the effect of soil conditions on this disease have been under way for some years. They consist of sand cultures in pots, and manurial plots.

The results obtained in sand cultures with various nutrients have been published (C118). The trees, after growing for three years under these conditions, were inoculated with *Pseudomonas mors-prunorum* (the organism which causes Bacterial Canker in plum trees) and when the cankers developed their size was recorded. The largest cankers were on trees which had received excess phosphate and the smallest on those to which no phosphate was supplied. It is suggested that these results may not be a direct result of presence or absence of phosphate but that they are probably correlated with the availability of iron. (F.H.B., H.W. and W.A.R.)

Young plum trees in plots receiving different manurial treatment were inoculated in the autumn of 1935 and the resulting cankers measured during the summer of 1936 ; the results have not yet been examined statistically. (H.W. and R.J.G.)

Bacteriosis of Cherry Trees.

Further study has been made of the various symptoms of disease associated with bacterial infection of sweet cherry trees, and cultural methods have been applied for a comparison of the parasitic organisms concerned.

Special attention has been given to the relative susceptibility of the varieties of cherry commonly cultivated and others included in the variety collection on the Station ; reports on these observations are being prepared for publication.

(H.W. and N.H.G.)

The organism found associated with a leaf spot in acid cherries has been used in inoculation experiments to test its parasitism ; in a preliminary experiment evidence was obtained that this organism is pathogenic. Cultural studies go to show that this organism is different from the two bacteria causing bacteriosis in plums and cherries in Britain. (H.W.)

Spraying Trials.

Spraying experiments have been carried out on this Station and in a grower's plantation. The results have been recorded but up to the present no definite conclusion can be drawn as to the efficacy of spraying for controlling these diseases.

(M.H.M. and H.W.)

Bacteriosis in Pear Trees.

A blossom wilt of pears associated with the presence of bacteria in the lesions has again come under observation. An organism has been isolated which is closely related to *Pseudomonas prunicola*, one of the organisms causing bacteriosis in plum and cherry trees. What appears to be the same bacterium has been isolated from spots on pear fruits also. The relationship of these organisms and the diseases with which they are associated is under investigation.

PATHOLOGY OF SMALL FRUITS.

75. Non-parasitic Disorders of the Raspberry.

Numerous serious local outbreaks of diseases of this character in the spring of 1936, mainly on the variety Lloyd George, were investigated in collaboration with the County Advisory Officers in Commercial Fruit Growing for Kent, and with Mr. B. S. Furneaux of the South-Eastern Agricultural College, Wye. The data collected indicate certain correlation of severity of attack and seasonal and soil conditions.

The soil moisture experiment to which reference was made in the 1936 report has yielded negative results. (R.V.H.)

76. Raspberry Mosaic Disease.

See special report on Raspberries under IX.

77. Loganberry Cane-spot.

See under " Loganberries, Blackberries and Dewberries ", XI.

78-79. Strawberry Diseases.

See special report on Strawberries under X.

MISCELLANEOUS.

80a. Verticillium Wilt of Hops.

In addition to the cases already under observation the disease has been observed in a number of other localities. Data were also collected throughout the year on the field experiments in progress on two farms in the Paddock Wood district. A further experiment was laid down at these two centres to determine the relation between the distribution of diseased hills and the height of the water-table. All these experiments have yielded positive results indicating close correlation of the incidence of wilt and soil drainage conditions. Work on the soil aspect of the investigations is being carried out in collaboration with Mr. B. S. Furneaux of the South-Eastern Agricultural College, Wye.

A paper on the disease was contributed to the Conference on Hop Growing at the South-Eastern Agricultural College on 15th January, 1936 and was subsequently published (C123). A brief outline of the progress of the investigation of this disease to date is given with reference to its symptoms, cause, incidence and control. The control of the disease is discussed from the point of view of soil treatments, grubbing diseased hills, the use of soil sterilants, the use of resistant varieties, and soil condition. (R.V.H.)

80b. A Wilt of Shoots in Layer Beds.

In recent years a wilting of shoots in the layer rows of plums, cherry and apricot stocks has come under notice at this Station. There is a fungus constantly associated with this disease and it appears to be the cause of the wilting. Until 1936 no fructifications of the fungus had been seen on these shoots and its identification could not be determined ; in 1936, however, fructifications were found and it was possible to identify the fungus as a species of *Cylindrocladium* closely related to (and perhaps identical with) *C. scoparium* which causes a Crown Canker in roses in Britain and the United States and a root rot of strawberry in Canada. (H.W.)

PUBLICATIONS DURING THE YEAR.

WORMALD, H. "A Slime-Fungus found on Strawberry Leaves." Gard. Chron. (9th November, 1935). **98,** 339, and E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 163. (C115.)

HARRIS, R. V. "Growing Healthy Raspberries—The Control of Diseases and Pests." Report of the R.H.S. Conference on Cherries and Soft Fruits, Varieties and Cultivation in 1935. 95-107, and E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 232-42. (C116.)

BEARD, F. H. and WORMALD, H. "Bacterial Canker of Plum Trees in Relation to Nutrition. Experimental Results in Sand Cultures (with an appendix by W. A. Roach)." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 146-54. (C118).

WORMALD, H. "Notes on the Silver Leaf Disease." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 155-7. (C121.)

WORMALD, H. "Notes on Plant Diseases in 1935." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 142-5. (C122.)

HARRIS, R. V. "The Verticillium Wilt of Hops. Some Facts and Recommendations." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 158-62. (C123.)

"Report on Mycology and Bacteriology for the year 1935." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 142-63. (C124.)

MONTGOMERY, H. B. S. "An Investigation of the temperatures lethal to some Wood-decaying Fungi." Trans. Brit. Mycol. Soc. (November, 1936). **20,** 293-8. (C125.)

SUMMARY.

An account is given of experiments made to determine the time, at certain temperatures, required to kill a number of wood-decaying fungi both in agar culture and also in moist wood blocks. The results are given in tabular form.

A new method is outlined for the experimental heat treatment of wood on a small scale, by the use of rubber bags.

VI. ENTOMOLOGY

81. Red Spider.

The Hop Red Spider.

The preliminary investigations made in 1935 have been continued, and it has been ascertained that the mite can be completely eradicated from the commercial plantation by the application of a pyrethrum spray applied in the spring. A progress report has been published (D119). (A.M.M.)

82. Woolly Aphis.

Control in the Nursery.

A bad outbreak occurred in the experimental nursery and provided an opportunity to carry out trials with sprays which could not profitably be used in fruiting plantations.

The results of work carried out in 1935 have been published (D116).

(R.M.G. and A.M.M.)

Resistant Seedlings.

During the year inoculation tests in the greenhouse for resistance to Woolly Aphis have been carried out on 1,534 seedlings raised at John Innes Horticultural Institution, Merton and at East Malling, and on 131 Russian seedlings which are now undergoing propagation tests at East Malling.

An account of all this work up to 1935 was published (D122).

(R.M.G. and A.M.M.)

Causes of "Immunity" of apple varieties to Woolly Aphis.

Further work on this problem was carried out during the year.

(R.M.G., W.A.R. and A.M.M.)

Bibliography.

A bibliography and survey of the literature on Woolly Aphis was compiled for the Imperial Bureau of Fruit Production to be published as their Technical Communication No. 8. (R.M.G.)

Tree Injection.

The suggestive but variable results obtained in 1935 in injection experiments to kill Woolly Aphis made it necessary to obtain further information on the exact source of the food of this species. Material was collected throughout the summer and is at present under examination. (R.M.G. and W.A.R.)

83. Impregnation of Corrugated Cardboard Bands.

The treatments which proved to be of value in the experiments of 1935 have been repeated on a field scale against weevils and codling larvae. A progress report on this investigation has been published (D120).

None of the treatments proved to be more attractive to weevils and codling larvae than the control bands, but the treatments which were found to be more promising in previous experiments were once again outstanding. Damage to bands by birds, mice, etc., proved to be less severe than previously. (R.M.G., A.M.M. and J.H.B.)

84. Tortrix Investigations.

The life-cycle of the Blackberry Shoot Webber (*Notocelia uddmanniana*), a pest of the loganberry and blackberry, is being worked out and experiments in relation to its control are in progress.

Other tortricids which occur on the genus Rubus are also being studied.

(G.H.L.D.)

85. A Study of the Vectors of "Reversion" of Black Currants.

This investigation is being held over until suitable material and accommodation is available. (A.M.M.)

86. Mites.

Systematic Study of Gall Mites.

A number of species sent here from abroad have been determined, and a new variety of mite found on White Beam in a Somerset garden has been recorded.

(A.M.M.)

Tarsonemid Mites.

It has been confirmed that the European Tarsonemid Mite of Strawberry is identical with the American Cyclamen or Pallid Mite, the correct name of the species being *T. pallidus* Banks. Other species in the group are being investigated. An undescribed species on blackberry has been discovered. (A.M.M.)

87-91.

See joint reports under IX and X.

PUBLICATIONS DURING THE YEAR.

Greenslade, R. M. "A Note on the Treatment of Dormant Nursery Stock against Woolly Aphis." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 184-5. (D116.)

Massee, A. M. "Studies on the Transmission of the Strawberry Virus 'Yellow-Edge' Disease by Insects. II. Aphid Transmission experiments and period of infectibility." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 171-6. (D118.)

Massee, A. M. "Notes on some Interesting Mites and Insects Observed on Hops and Fruit Trees in 1935." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 164-70. (D119.)

Greenslade, R. M. and Massee, A. M. "Studies of Impregnation of Tree Banding Materials. II. Apple Blossom Weevil and Codlin Moth Experiments in 1935." A Progress Report. E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936). 177-83. (D120.)

Crane, M. B. (John Innes Hort. Inst.), Greenslade, R. M., Massee, A. M. and Tydeman, H. M. "Studies on the Resistance and Immunity of Apples to the

Woolly Aphis (*Eriosoma lanigerum* (Hausm.))." Journ. Pom. and Hort. Sci. (July, 1936). **14,** 137-63. (D122.)

SUMMARY.

1. The life-cycle of the Woolly Aphis, *Eriosoma lanigerum* (Hausm.), is outlined, and the hereditary behaviour of the apple in respect of immunity to its attack is described, and the term " immunity " as used in this paper is defined.

2. An account is given of the entomological technique used in testing for resistance and immunity, and of preliminary physiological investigations on the underlying causes of immunity.

3. A genetical analysis is made of the families raised from crossing established varieties of apples with a number of forms commonly used as rootstocks. The seedlings have been derived from susceptible × susceptible, immune × immune, susceptible × immune and a few small families from selfing immune and susceptible forms. A total of 3,758 seedlings have been raised, entomologically investigated, and their susceptibility or immunity determined.

4. It is tentatively concluded that the immunity to attack is determined by and dependent upon a certain balance of genetic factors, and that it is governed by a number of genes the action of which is in part complementary and in part cumulative.

5. A preliminary account is given of the characters of some of the immune seedlings.

GREENSLADE, R. M. " Horticultural Aspects of Woolly Aphis Control together with a Survey of the Literature." Imp. Bur. Fr. Prod. Tech. Comm. No. 8 (October, 1936). (D125.)

SUMMARY.

The published information on *E. lanigerum* is reviewed.

The aspects of the problem which are most interesting to horticulturists are fully discussed.

The insect and its habits in Europe and America are described, and an account is given of the damage done by it.

The effect of climate on the seriousness of its incidence is noted.

The control of the insect by spraying, by biological methods, and by the use of resistant varieties, is considered.

An annotated bibliography of 600 references is appended.

VII. INSECTICIDES AND FUNGICIDES

LABORATORY INVESTIGATIONS.

93, 98, 99, 100. Insecticides.

Methods of Testing.

The investigation of methods for testing insecticides has been continued, and the experience gained thereby has been applied to the examination of the toxic properties of the various materials mentioned below. (W.S.)

Tests of Ovicides.

The investigation of the toxic properties of tar distillates (carried out with the co-operation of the Fuel Research Station, Greenwich) has been extended to include high temperature carbonization tar oils. The neutral, phenolic and basic fractions have been further separated into smaller fractions according to boiling range and the ovicidal action of these fractions determined. Interesting results have been obtained but a satisfactory correlation of properties is not yet possible.

The ovicidal properties of numerous organic chemical individuals have been investigated. Most of these substances have been selected from those known to be present in tar distillates, in particular, the heterocyclic bases. Other substances examined included various organic thiocyanates, certain chlorinated naphthalenes, two nitrophenols, nicotine and anabasine.

Certain industrial materials and by-products have also been examined for ovicidal properties. (H.S. and W.S.)

Tests of Contact Insecticides.

The materials examined during 1936 have consisted largely of chemically individual substances including many organic thiocyanates, certain thiophenols, anabasine and thiodiphenylamine. The last named has been found to be of particular interest.

A few commercial products have also been examined. (H.S. and W.S.)

Tests of Stomach Poisons.

No systematic investigation is at present in progress or contemplated. Of the few materials tested, thiodiphenylamine has been found outstanding. To certain insects it is considerably more toxic than lead arsenate. An intensive exploration of the practical possibilities of this substance is in progress. (H.S. and W.S.)

Chemical Aspects.

The relation of chemical constitution to insecticidal action has been further studied as opportunity has arisen.

During the late summer and autumn of 1936, a long series of analyses was carried out to determine the amounts of arsenic on fruit picked from trees to which lead arsenate had been applied at various intervals before picking time. The information so obtained will be utilized in the elaboration of measures to control the Codling Moth (see pp. 250-8).

Analyses of proprietary and commercial preparations have been made and the results obtained have been used in the planning of certain experiments and in the interpretation of the results of others. (H.S.)

95, 100. Fungicides.

Methods of Testing.

The method evolved for testing protective fungicides has been further developed and is the subject of a full report now in preparation for the press.

(H.B.S.M. and M.H.M.)

Tests of Fungicides.

A fairly wide range of new chemical preparations has been tested and some of them are promising, especially tetramethylthiuram disulphide.

(H.B.S.M., M.H.M. and H.S.)

Chemical Aspects.

In determining the fungicidal activity of chemically-individual substances, special attention has been given to the differences arising as the result of changes in molecular structure. (H.S.)

FIELD INVESTIGATIONS. I. MODIFICATION OF ROUTINE CONTROL MEASURES.

96A. Insecticide-Fungicide Programme for Cox's Orange Pippin.

Following the results obtained in 1935 (C119), a further field spraying trial showed that two pre-blossom lime-sulphur sprays (applied at green-bud and at pink-bud) were yet again more efficacious than one (applied at pink-bud).

Scab-infection became very severe during the wet 1936 summer, yet a four-application spraying-programme (two pre- followed by two post-blossom) gave very good control (see pp. 259-75). Lime-sulphur gave as good control when used at 1 per cent. throughout as when a 2·5 per cent. dilution, pre-blossom, was followed by a 1 per cent., post-blossom. The inclusion of a spreader did not improve the control.

A very weak Bordeaux mixture (2-10-100) gave good Scab-control but caused severe fruit-russeting. Two pre-blossom applications gave no better control than one.

Nicotine included at petal-fall gave very good control of Sawfly ; the degree of control was not affected by the addition of a spreader.

The addition of lead arsenate to the second post-blossom spray gave inconclusive results against Codling since the infestation was very low.

(H.B.S.M., M.H.M. and W.S.)

96B. Spreader Trials—Apple Scab.

Lime-sulphur controlled Scab as well without, as with, a spreader, and no significant difference was shown between the results afforded by each of several different spreaders tested. The trial was conducted on young trees of Worcester Pearmain, Edward VII, Allington Pippin, and Newton Wonder, all on No. IX stock.

(H.B.S.M. and M.H.M.)

96, 100. Mitigation of Spray-Damage.

By addition of Ferrous Sulphate.

The trial on Cox's and Worcesters on No. II stock was continued, and clear evidence was obtained that the inclusion of ferrous sulphate had a beneficial effect in protecting the trees from defoliation by lime-sulphur, applied at 1-60 post-blossom, with or without lead or calcium arsenate. Evidence was also obtained that some of the spray-injury was due to the presence of the arsenates, that of calcium being the more harmful. All the sprays caused severe fruit-drop, there being but slight evidence here of the beneficial effect of the ferrous sulphate. (H.B.S.M. and M.H.M.)

Chemical analyses have shown that the reduction of spray-damage in the case of lime-sulphur-lead arsenate sprays can be partially explained on the basis of the amount of arsenic present in solution. (H.S.)

By reduction of Spray-Concentration.

No separate trial, as in 1935, was made under this heading, but the work was included under 96A. Weak lime-sulphur, at 1 per cent., pre-blossom, caused no injury, while at 2·5 per cent., it caused some marginal leaf-burn. Weak Bordeaux mixture (2-10-100) was very harmful to Cox's. At 3-9-100, in another trial (see below), it caused severe injury to young trees of Worcester Pearmain, Edward VII, Allington Pippin, and Newton Wonder: lime-sulphur, used in this trial at the same dilution as under 96A, gave results similar to those already mentioned. (H.B.S.M. and M.H.M.)

FIELD INVESTIGATIONS. II. TESTS OF NEW SPRAY MATERIALS.

94, 96, 98. Phytocide Trials.

The phytocidal properties of many substances, preparations and combinations have been determined as a preliminary to further trials. A rational study of the problems of phytocidal action is being made and interesting and suggestive relationships have been noted. (H.S. and W.S.)

94, 99. Insecticide Trials.

Emulsifiers for Mineral Oils.

An examination of commercial emulsifying agents has been undertaken with a view to finding, if possible, a material suitable for the preparation of home-made oil sprays. One proprietary material has shown such potentialities as to justify extended field trials. Such results as are available confirm the early promise of the material (see pp. 246-9). (H.S. and W.S.)

Mineral Oils.

Several relatively cheap grades of mineral oil are under examination to determine whether or not any one of them can satisfactorily replace the more expensive summer grade oils at present in use. The opportunity is being utilized to compare the phytocidal properties of these oils with their chemical and physical characteristics. (H.S.)

96. Fungicide Trials.

Three new sprays containing elementary sulphur, and one new copper-containing spray, were compared respectively with lime-sulphur and with Bordeaux mixture,

all suitably diluted to contain equivalent sulphur or copper as far as possible. The trial was made on young trees of Worcester Pearmain, Edward VII, Allington Pippin, and Newton Wonder. Both the copper sprays gave good Scab-control but caused severe injury, while none of the new sulphur sprays, which caused no injury, proved to be as effective fungicidally as lime-sulphur, which caused fruit-drop (see pp. 259-66).

A report on the 1935 investigations was published during 1936 (C120).

(H.B.S.M. and M.H.M.)

FIELD INVESTIGATIONS. III. BIOLOGY AND CONTROL OF SPECIFIC PESTS AND DISEASES.

92, 94. Codling Moth.

The habits of this pest have been further studied. Several field spraying trials were carried out but, as the infestation was very low, the results were somewhat inconclusive. Some confirmation was obtained of the desirability of spraying with lead arsenate in late June (see pp. 250-8). (W.S.)

94. Plum Sawfly.

A trial carried out at Addington through the courtesy of Mr. R. Thompson demonstrated the value of derris root and the inefficiency of nicotine for the control of this pest. (W.S.)

94. Red Spider.

Winter spraying trials were carried out in conjunction with laboratory trials. The results given by a cheap mineral oil were good irrespective of the method of emulsification employed. Moreover it may prove possible, given suitable emulsifying materials, to control the pest satisfactorily with concentrations of oil lower than the 5 per cent. normally used. (H.S. and W.S.)

Summer spraying trials of wetters for use with lime-sulphur and of summer petroleum-oil emulsions were also carried out. The addition of wetters did not improve the performance of lime-sulphur which itself, under the exceptional weather conditions of 1936, gave very poor results. Good control was obtained with a summer oil (at 1 per cent. and even at 0·5 per cent. concentration) but reinfestation rapidly occurred. (W.S.)

96. Brown Rot in Morello Cherries.

Spraying in mid-February with tar-oil winter wash, diluted to contain approximately 5 per cent. or 2·5 per cent. of neutral tar oil, gave very good control of Brown Rot by " burning " the spore-pustules on the shoots killed by the disease during the previous year's flowering period. The stronger spray gave slightly the better result.

Spraying once, or twice, just pre-blossom, with Bordeaux mixture (8-12-100) or with lime-sulphur (2·5 per cent.) also gave good control ; infection on the controls, however, was only moderate in this instance. Lime-sulphur caused appreciable " burning " of the flower-buds, which delayed flowering : most of the flowers on all trees were destroyed by frost.

The cutting-out of infections in winter, without any spray-treatment, also resulted in good control. (H.B.S.M. and M.H.M.)

96. Strawberry Mildew.

Lime-sulphur (2 per cent.), with or without a spreader, and sulphur dust, all proved effective as protective fungicides when applied once, or twice, pre-blossom. Ease of application would render dusting the more attractive commercially. (M.H.M.)

96. Bacterial "Shot-hole" and Canker in Stone Fruits.

Applications of Bordeaux mixture in both autumn and spring effected a reduction by two-thirds in the incidence of new cankers and "bud-infections" in Bigarreau de Schrecken cherry. Applications in autumn only, or in spring only, showed a slight beneficial effect. Data on "shot-hole" were not forthcoming owing to the relative freedom of the leaves from infection.

Injury (leaf-burn) from Bordeaux mixture (8-12-100) occurred on Schrecken, Napoleon, Early Rivers and, slightly, on Frogmore, all of which were being used for spraying tests against this disease.

A spraying trial was begun in autumn, 1936, on young Victoria plum trees, but it has not yet progressed far enough to yield results. (H.B.S.M. and M.H.M.)

97. Apple Scab.

Records made on fruits of Bramley's Seedling, from trees on different rootstocks and under different manurial treatments, suggested that the incidence of Scab was greatest in the presence of excess nitrogen. Least Scab was found where potash alone was given. The kind of rootstock influenced to some extent the degree of infection.

Similar records made on Cox's Orange Pippin gave inconclusive results owing to high variability among the figures for similarly-treated trees.

The data so far obtained on the relationship between manurial treatment and the incidence of Scab were published during 1936 (C117). (H.B.S.M. and M.H.M.)

97a. "Branch-Blister" Disease.

Specimens continue to be received, especially of young Cox's Orange Pippin on No. II stock. Several growers report natural recovery, doubtless due to the presence of more moisture in the soil, thus permitting the better establishment of newly-planted trees. Experiments undertaken in the field in Essex showed conclusively that soil conditions are a major factor in the incidence of the disease. The results obtained from pot experiments made in Essex have so far failed to support the data obtained in the field. It is probable, however, that field conditions were not satisfactorily reproduced in the pots. (M.H.M.)

PUBLICATIONS DURING THE YEAR.

Steer, W. "Observations on Codlin Moth (*Cydia pomonella* L.) in 1935." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936), 186-90. (D117.)

Steer, W. "The Use of Derris Root as an Insecticide." E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936), 225-7. (D121.)

MOORE, M. H. "Some observations on the influence of manurial dressings and of certain other factors on the incidence of Scab (*Venturia inæqualis* (Cooke) Wint.) and of spray-injury in apples." Journ. Pom. and Hort. Sci. (April, 1936), **14,** 77-96. (C117.)

SUMMARY.

Although the differences between the results of treatments were not large, for reasons given, the data suggest that the degree to which *Venturia inæqualis* caused infection of the fruits of Bramley's Seedling and of Worcester Pearmain was governed by the manurial treatment of the trees, by grassing-down, by pruning, by seasonal conditions, and by the rootstocks on which the trees are worked. There were indications that, in general, nitrogenous manuring increased susceptibility to Scab, while grassing-down decreased it. Rootstock-influence showed differential reactions to these stimuli, and weather conditions provided a further source of variation in response.

Fruit-russeting on Bramley's Seedling in 1934, caused by Bordeaux mixture applied at petal-fall, was rather more severe on trees receiving only nitrogen than on those receiving potash, nitrogen with potash, or no manure. Its severity was influenced also by rootstock.

MOORE, M. H. and MONTGOMERY, H. B. S. "A field spraying trial of combined fungicide-contact-insecticide sprays in 1935." A Progress Report. E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936), 191-7. (C119.)

MONTGOMERY, H. B. S., MOORE, M. H. and SHAW, H. "Field Trials in 1935 of the fungicidal and phytocidal properties of certain new chemical preparations." A Progress Report. E. Malling Res. Sta. Ann. Rep. for 1935 (May, 1936), 198-203. (C120.)

VIII. EXTERNAL CONTACTS

101. Enquiries and Visitors.

Some 1,929 written enquiries have been replied to in the course of the year and a large number of telephone enquiries have been dealt with. Visitors to the Station numbered 3,070, including 142 visitors from overseas and 54 organized parties.

(N.B.B., H.C.C., and the staff in general.)

102. Conferences, Demonstrations and Lectures. Exhibits and Publications.

Three conferences and three open days have been held, and sixteen lectures given by members of the staff. Nine educational exhibits have been staged at agricultural or horticultural shows and forty-five publications have been published, including popular articles and bulletins.

For further details of External Contacts see the Supplementary Annual Report (twenty-fourth year) General Development and Activities (Misc. Publ. A21.).

IX. RASPBERRIES

(Combined Pomological and Pathological Investigations.)

42. Variety Trials.

One fresh variety was added to the collection in the past year ; already five or six more are promised for planting during the winter.

The first crop of fruit of the new American seedlings recently received does not suggest that any of them will be specially well adapted to English conditions. As, however, Newburgh, now the most promising American variety in the trial, was also poor in its first year of cropping, they may yet show a great improvement.

(N.H.G.)

47. Breeding.

Seedlings of six new families were planted out in 1936, and seed was sown of nine further families. The latter include selfs and crosses of the American red raspberries Newburgh and Taylor, and a cross with the black raspberry Naples. Three seedlings of mosaic resistant parentage have also been selfed with a view to studying the mosaic relationship of their progeny. (N.H.G.)

50. Propagation.

The number of varieties of commercial importance obtainable free from mosaic is severely limited ; several even of the newer varieties appear to show mosaic symptoms in every plant. Efforts are therefore being made to work up clonal mosaic free stocks of such varieties as Norfolk Giant and the New Zealand " Hornet " (believed to be Hornet A), which are at least useful in certain districts. (N.H.G. and R.V.H.)

55. Pruning and Thinning.

This work is in abeyance.

59. Manuring.

The second year's cane growth and the first crop of the combined seedling and manurial trial do not show as yet any striking effects of the manurial treatments—potash in varying amounts.

The four seedlings have shown their individuality more clearly than before ; they differ considerably in vigour, habit, and size and colour of fruit. At present all are more vigorous than either of the two named varieties included in the trial, Lloyd George and Maclaren's Prolific. (W.A.B. and N.H.G.)

76. Raspberry Mosaic Disease.

Experiments from 1927 to the present time have shown that attacks of mosaic disease are complex in their causal nature, being referable to the action of three (at least) distinct viruses, the isolation and comparative study of which thus becomes a necessary preliminary to the propagation of healthy cane planting stock.

Progress in this analysis of symptoms with the present limited glasshouse accommodation and assistance has been necessarily slow owing to the laborious and lengthy nature of determinations by the only available method of transmission (viz. by grafting), and to the hitherto negative results from experiments in methods of mechanical transmission, and animal vector determination.

Transmission Experiments.

The results of the grafting experiment in 1935 only became available in 1936. Of sixty-three grafts twenty-two were successful and these were limited to six only of the fifteen types of combination used. In 1936 an experiment to supplement the fragmentary data from that of 1935 was made when the proportion of successes was somewhat higher (approximately 50 per cent.) but again five of the nine types of combination were complete failures, suggesting that an incompatibility factor militates against adequate success of the method of grafting employed. The results of the latter experiment will not be fully available till 1937. (R.V.H.)

Experiments in Commercial Control.

Pending the determination of the essential preliminary data on other varieties, these experiments are still limited to the Lloyd George variety. During 1936 available time has only allowed the inspection of two of the five original extension cane-nurseries. In conjunction with parallel work on strawberry-runner propagation it was also possible to inspect, in addition, four cane-nurseries recently planted with a new clonal stock of this variety. All these inspections have yielded satisfactory and encouraging results, indicating that under a regular and uninterrupted series of inspections and roguings the health and vigour of the original stocks of cane issued from East Malling are being adequately maintained.

In addition to the above inspections, routine roguings of the East Malling parent cane-nurseries were carried out and some 15,000 canes were distributed in small units (" cane-nuclei ") to growers, in the winter of 1935-6, for the establishment of further propagation centres. (N.H.G. and R.V.H.)

Experiments in Field Rate of Spread (Infectibility) and Susceptibility.

An experimental plot was established in 1936 for the determination of methods of routine field testing of varieties for the above with a view to speeding up the lengthy process involved in greenhouse testing of pot material. (N.H.G. and R.V.H.)

Raspberry Insects. Determination of Animal Vectors of Mosaic.

Further observations on the experiment carried out in 1935 have again yielded negative results. This important aspect of the investigations is in temporary abeyance pending the provision of adequate insectary equipment. (A.M.M.)

X. STRAWBERRIES

(Combined Pomological and Pathological Investigations.)

44. Classification, Nomenclature and Variety Trials.

Clonal races of important varieties and "strains" have been kept under observation. (W.S.R.)

48. Breeding.

No further crosses were made during the past season. A number of seedlings raised at the John Innes Horticultural Institution from crosses between Royal Sovereign, Cessnock and Marcienfelde were sent to East Malling for trial. They have been planted out but have not yet fruited. (H.M.T.)

52. Propagation.

The establishment of virus-free Clones.

A large quantity of our selected clonal Royal Sovereign was available for runner raising in 1936. Some 14 acres of runners were raised on the isolated block system, with cultivated alleys between each 3 ft. square block of runners. As a result of the wet summer the amount of labour required to keep the runners laid in and the beds weeded was very great. Systematic inspections and roguings were carried out over the whole area throughout the season—a large piece of work in itself—and it was satisfactory to find that the material showed a very high degree of freedom from virus symptoms.

The total number of runners produced approached one million.

The preliminary nursery trial of other varieties and strains unfortunately showed a rather large amount of virus infection, possibly due to the presence of varieties now suspected of being "symptomless carriers" of the disease. Fresh selected clones of each variety have been planted in two new trials, one for the "suspected carriers" and another for the other varieties. (W.S.R. and R.V.H.)

Individual Plant Studies of Clonal Families.

The records of the individual life histories of over 3,000 plants are still in process of being summarized. (W.S.R. and J.L.E.)

Uniformity Trials.

Plant to plant records of various plots, including one which for the present has uniform treatment, are providing further material for calculation of the ideal strawberry plot for various purposes. (J.L.E.)

Effect of Age of Parent and Spacing of Runners.

In this preliminary trial of runners from one- and two-year-old parents and runners that were spaced and unspaced in the runner bed it appears that neither age of parent nor spacing of the runners is a major factor in the subsequent growth or fruiting of the plant. Runners from one-year-old parents tend to be larger than those from two-year-old parents, and spaced runners tend to be larger than unspaced runners,

but once they become established they all appear to behave much alike. Such differences as were found coincided with differences in incidence of virus infection.

The " age of parent trial " will be repeated. (W.S.R.)

57. Planting, etc.

Time of Planting in Relation to Warm Water Treatment.

The trial of warm water treated and untreated runners planted monthly from September 1934 to April 1935 has confirmed previous results, showing that the best period to plant under our conditions is early autumn. It is particularly desirable to avoid planting warm water treated plants in the winter, as heavy losses will result.

A further repetition of this trial is under way. (W.S.R., A.M.M. and C.P.F.)

Effect of Planting Strawberries after Strawberries.

Data are being accumulated on a preliminary trial, comparing the behaviour of strawberries on land which had previously been cropped with strawberries and land which had not. (W.S.R.)

Burning in Relation to Pest Control.

A new experiment in which the effect of burning the straw litter can be observed has been planted. The treatment will be applied in the summer of 1937.

(W.S.R. and A.M.M.)

60. Manuring.

The preliminary trial planted in October, 1935 has grown well and has already given some suggestive results. The treatments are—(*a*) Tares ploughed in before planting, and (*b*) no tares, with three complete fertilizer dressings and a control. The complete fertilizer dressings are—(1) meat and bone meal, (2) similar amounts of N, P, and K, in a mixture of sulphate of potash, superphosphate, steamed bone flour and sulphate of ammonia, and (3) a similar dressing with the sulphate of ammonia replaced by nitrate of soda.

Three planting distances were included in the main trial.

Some plants were dug up at fortnightly intervals after planting, and these showed that new roots did not form so readily on the land where tares were ploughed in as on the land which had no tares. The looser texture of the former may have contributed to this effect.

In another trial comparing a heavy dressing of farmyard manure with no manure the plants having farmyard manure have grown much more vigorously than the control plants. These trials will fruit in 1937. (W.S.R.)

78. Virus Diseases.

Field Experiments.

A further season's records on the field propagation experiment (started in 1935) to determine the relation of symptom expression to cultural and seasonal conditions have yielded results confirming those of the past year and indicating definite correlations of such. An account of this experiment is in course of preparation.

In collaboration with Pomology and Entomology a field experiment was planted up in March, 1936 to determine under " fruiting plantation " conditions the mode of

natural spread of virus disease and the performance of individual plants, from the time of infection, on plots subject to contrasted manurial treatments and to roguing and/or aphicidal spraying during the initial season.

Transmission experiments with Pot Material.

Varietal susceptibility to Yellow-edge.

Observations in 1936 on the plant material of the 1935 experiments have confirmed that the wide range of susceptibility to the disease determined both in the case of American and English commercial varieties can be interpreted in terms of the contrasted reactions of the parent species of *Fragaria* common to all these varieties. *Fragaria chiloensis* has been shown by these experiments to be capable of acting as a " symptomless carrier " of the disease, with high resistance, and *F. virginiana*, in complete contrast, to be highly susceptible, with continuous symptom expression. Thus, for example, commercial varieties such as Lefebvre approximate closely to the reaction of the former species and Royal Sovereign to the latter.

Common wild strawberry (F. vesca) as an indicator of virus diseases.

The use of this species as an indicator suggested by certain indirect results of the 1935 experiments, was confirmed by a large-scale experiment in 1936. Samples of plants from five clonal families of Royal Sovereign (including the clonal family used for bulk distribution) were tested by runner-grafting each plant to a normal *F. vesca* indicator. In spite of the uniformly healthy appearance of all the plants under test throughout the 1936 season, a wide range of symptoms of both the " Yellow-edge " and " Crinkle " types, singly and combined, developed on this " indicator ". By this method cases of infection by both Yellow-edge and Crinkle have been detected in the absence of diagnostic symptoms on the plants under test. In this connection it is interesting to note that no Yellow-edge was indicated in any plant from the main East Malling clonal family mentioned above. The complete results of this experiment will not be available till 1937.

The Distribution and Etiology of Yellow-edge and Crinkle.

The 1936 experiments have confirmed tentative conclusions from previous work in the following particulars :

(*a*) The proportionate incidence of Yellow-edge has been drastically and adequately reduced in certain clonal races of Royal Sovereign by the systematic series of inspections and roguings imposed on the runner beds.

(*b*) Crinkle is widely distributed in local stocks of Royal Sovereign and other varieties both in combination with Yellow-edge and (in the case of the Yellow-edge rogued clonal races) alone, mainly in " mild " form.

(*c*) The Crinkle group of symptoms is complex in causal origin, i.e. " severe " (or " advanced ") crinkle differs in causal origin from " mild " crinkle.

(*d*) That the Yellow-edge virus exists in " multiple-strain " form.

Investigations of Virus Diseases in Ontario.

The results of the above 1935 and 1936 experiments at East Malling were found to throw considerable light upon this investigation, started in 1933-4 under an Exchange-of-workers arrangement, an account of which, to date, has been prepared for publication by the present writer and his Canadian collaborator.

It will be seen from the above that whereas in 1930 we were working with a single group of symptoms, we now have to regard these and other symptoms as of complex origin and referable under each of the two main groups (Yellow-edge and Crinkle) to two or more distinct viruses or strains of virus. The evaluation of each of these viruses and strains in relation to the strawberry grower becomes a matter of urgent importance having as its objective the issue of stocks of runners with a degree of uniform "virus-freedom" and potentiality higher than that of the "Yellow-edge-rogued" stocks raised in the early stages of the work. Parallel with the selection and testing of new clones of Royal Sovereign and other varieties with the best possible indicator available, further research with a view to identifying indicators with more sensitive reaction, and improved methods of artificial transmission is urgently required and will be carried out as far as the present limited greenhouse equipment, time and man-power permits.

(R.V.H.)

87. The Strawberry Tarsonemid Mite.

Life-cycle.

A study of the life-cycle of the mite is still under investigation, but owing to the minute size of this pest, the work must of necessity be slow.

Relation to Yellow-edge.

The experiments conducted over a period to determine whether the mite is a vector of Yellow-edge have shown negative results, and it is clear that the mite is not associated with this particular virus.

Control.

Warm water treatment. See under Planting, etc.

Spraying.

Further tests of acaricides and other sprays have been made under field conditions, but the control of this mite presents very special problems and until a spray can be found which will penetrate the hairy, folded strawberry leaves little progress can be hoped for.

Natural Enemies.

The search for natural enemies is still in progress. (A.M.M. and R.M.G.)

89. Strawberry Aphid Investigations.

Aphid transmission experiments and period of infectibility.

These experiments indicate that the aphid can transmit Yellow-edge during seven months of the year. Details of this work have been published (D118).

Life-cycle with special reference to alternate hosts in the Field.

Observations have been made upon this insect with a view to finding out at what periods of the year strawberry runner beds become infested with new colonies of aphids, and also the natural spread in the field.

Further efforts have been made to find its natural alternative host plants.

(A.M.M.)

Control by Sprays and Dusts.

Little progress has been made in this direction owing to the difficulty of spraying or dusting strawberries efficiently on a commercial scale. It has been shown, however, that a wet spray is far superior to a dust, and that certain spreaders and wetters are more efficient than others. (R.M.G. and A.M.M.)

90. Insects Feeding upon the Strawberry Plant.

Of the many insects recorded upon the strawberry, experiments have been started with the Rose Leaf Hopper (which is also associated with strawberry) to determine whether it is able to transmit the Yellow-edge disease. Owing to the rapid jumping movements of this insect progress must of necessity be slow until adequate insect-proof houses are available to facilitate this study.

Other insects occurring commonly on strawberry are also being studied.

(A.M.M.)

91. The Warm Water Treatment.

Modifications of methods of technique are being continued.

(A.M.M. and W.S.R.)

XI. LOGANBERRIES, BLACKBERRIES AND DEWBERRIES

(*Combined Pomological and Pathological Investigations.*)

43. Classification, Nomenclature and Variety Trials.

Vigour, cropping and observational records have been continued on :

(*a*) The collection of blackberry and dewberry varieties.
(*b*) The loganberry variants.
(*c*) The blackberry seedlings from John Innes.
(*d*) A complex trial of clonal loganberry and Phenomenal Berry.
(*e*) A trial of clonal Himalaya and Black Diamond blackberries.

All these trials yielded a good crop in 1936. Samples of the fruit of each variety, in trials (*d*) Loganberry and Phenomenal Berry and (*e*) Himalaya and Black Diamond, have been sent to the Fruit and Vegetable Preservation Research Station, Campden, for an investigation of the canning quality which is being carried out in collaboration with Mr. F. Hirst. From trial (*d*) sixteen samples, of which eight had received the combined, and eight the single spray treatment referred to under 77B, were sent to Campden. From trial (*e*) four samples were sent. This investigation will be continued over a period of years, so that the effect of seasonal conditions may be eliminated. (A.B.B.)

53. Propagation.

The clonal stool beds have been extended to include some new varieties of blackberries and dewberries. (A.B.B.)

58. Training.

The loganberry and Phenomenal Berry trial 43*d*, was so free from cane-spot disease during 1936 that it was impossible to tell whether any of the four training methods used was superior to the others in preventing the spread of cane-spot from the old to the young cane. All four methods appear to give good healthy plants.
(A.B.B. and R.V.H.)

77B. Loganberry Cane-spot.

Four blocks of clonal loganberry and Phenomenal Berry plants in trial 43*d* were given a combined spray designed to control loganberry beetle and cane-spot disease and four blocks were given a spray to control loganberry beetle only. The vigorous young plants in this trial were so free from cane-spot during 1936 that no difference in the incidence of cane-spot disease was visible between plots which had received the combined and those which had received the single spray. (R.V.H. and A.B.B.)

86A. Blackberry Mites.

A preliminary spraying trial has been conducted on the clonal Himalaya and Black Diamond blackberries 43*e*, to determine whether either of the Gall Mites, *Eriophyes essigi* Hassan and *E. gracilis* Nalepa are in any way associated with a disease of Rubi

known as " Red Berry Disease ". The life-cycle of the two species are being worked out in the laboratory and in the field.

An undescribed species of Tarsonemid Mite has also been recorded on blackberry. (G.H.L.D. and A.B.B.)

104. " Reversion " Disease of Blackberry and Loganberry.

Numerous cases of this disease have been recorded on the experimental plots and on local farms during the 1936 season and material has been marked for future experiments to determine its cause. (A.B.B. and R.V.H.)

Section III

PRELIMINARY RESEARCH REPORTS

POMOLOGY

THE ROOT SYSTEMS OF SOME NEW VARIETIES OF APPLE ROOTSTOCK

By H. M. TYDEMAN

STUDIES have been in progress for a number of years upon a series of seedling apple rootstocks, raised by Mr. M. B. Crane of the John Innes Horticultural Institution in 1923, from a cross between Malling No. VIII (French Paradise) × Malling No. IX (Jaune de Metz). After studying the unworked seedlings at Merton for a number of years, Crane sent them to East Malling because it was thought that some of them might prove promising dwarfing or semi-dwarfing rootstocks. Of the total of 136 seedlings originally sent, nineteen were ultimately selected because they could be propagated readily. They were multiplied in quantity and are being tested with the variety Lane's Prince Albert, to ascertain their influence upon the scion variety. As has been reported elsewhere (1, 2), they have been found to make trees varying widely in size and productivity when worked with Lane's Prince Albert.

During the winter of 1936 it was possible to dig up the trees on a preliminary trial plot containing nine of these rootstocks, budded with Lane's Prince Albert in 1932, as it had been superseded by a more complete trial. The opportunity was taken for making a detailed analysis of the root systems. The trees were somewhat closely planted, at approximately two feet apart, in rows four feet apart. There were fifty trees upon each seedling rootstock, growing in five blocks, randomized throughout the plantation, with units of trees upon Malling Nos. VII and IX as controls.

The trees upon which the principal observations were made were excavated by the method which has been largely employed by Rogers (3). A trench sufficiently large to include the entire root system was opened up upon one side of the tree and slowly driven forward until all the roots had been recovered. By this method it was possible to excavate the entire root systems more or less as a whole, although, owing to the extremely brittle nature of the roots of these VIII × IX seedlings, and to the fact that the root systems of the different trees had become interlaced to a certain extent, a proportion of the roots had actually become severed from the trees. Supplementary observations were possible upon a further series of ten trees, upon each rootstock, which were dug up in a much more superficial manner. The results of the analysis of these root systems are summarized in the table.

In their general conformation the root systems of the trees on these rootstocks resembled one another very closely. They did not penetrate to any considerable depth because extension downwards was apparently limited by the presence of considerable quantities of stone comparatively near the surface. On the other hand, the roots spread

more or less horizontally for relatively long distances between the rows. The table shows that the roots of the trees on the more vigorous rootstocks, Nos. 125, 128 and 112, reached an average spread of about three metres which is a fairly extensive range for the roots of four-year-old trees. The figures illustrate clearly the very constant relation which existed between the weight of the root system and the total weight of the tree among the different rootstocks. The most outstanding differences which were to be found in the morphology of these root systems, however, were in the relative amounts of fibre and in its distribution upon the framework of the main roots.

(*a*) Relative Amount of Fibre on the Root System.

The table shows that there were wide differences in the relative amounts of fibre on these root systems. Thus, in the series of trees in which the entire root systems were excavated, the fibre on the root system, that is all roots of less than 2 mm. in thickness, comprised as much as 18·5 per cent. of the total weight of the roots in trees on No. 9, and as little as 6·6 per cent. in trees on No. 29. As might have been expected, the proportion of fibre to total roots was greatly increased on the trees which had been more roughly dug up, ranging from 8·1 per cent. in trees on No. 90 to 28·6 per cent. in the trees on No. 9. The results on the latter series of trees are, to a large extent, cut across by differences in the relative distribution of the fibre to be discussed in the next section.

The differences in the relative amount of fibre on the root systems of the trees on these rootstocks are seen to have been fairly considerable and were certainly too large to have been attributable to chance variation in the material, particularly as the results were based on an analysis of ten root systems in each case. While the range appears to be fairly continuous and there is no very striking evidence of a segregation into distinct classes of more or less well-fibred systems, this does not invalidate the conclusion to which these results appear to point, that a genetic segregation for this character has occurred, although the class intervals were not sufficiently large to have become clearly apparent in the somewhat variable material which was being studied.

(*b*) The Distribution of the Fibre on the Root System.

It was apparent to the eye, when the root systems of the trees on the various rootstocks were compared, that considerable difference existed between them, in the relative position of the fibre on the main framework of the root system. It was a comparatively simple matter to distinguish series of trees in which the fibre was borne towards the top of the scaffolding of main roots and others in which the fibre was distributed evenly and continuously throughout the whole system. Although such a distinction could be made with comparative ease by eye, it was not found a very simple matter to obtain definite measurements by which it could be recorded. Owing to their extreme brittleness and the rather difficult nature of the soil from which they were being excavated, it was not always found possible to extract the root systems in a complete state and their subsequent reconstruction for the type of extremely precise analysis required would have proved impracticable. Fortunately, a somewhat more indirect method of approach was found. As has already been pointed out, one series of ten trees on each of these rootstocks was dug up in a more or less superficial manner to supplement the observations on the series of ten trees which were excavated in a complete state. From measurements of the depth and spread of the roots and a comparison of their relative weights, it was calculated that, in the former series of trees, approximately one-half of the total root system was recovered. Since this half was, of course, the upper half of the root system, in those cases in which the whole of the fibre was in the upper

part of the root system, it would all be recovered in the trees dug up in this way. On the other hand, in those trees in which the fibre was distributed evenly throughout the entire root system, only one-half would be recovered, the remaining half being on those roots which were left in the soil. It will be understood that in those trees in which the entire root systems were excavated, the whole of the fibre would be recovered in every case. A comparison of the weight of fibre relative to that of the coarse root on the trees on the various rootstocks would, at once, reveal whether any difference in the distribution of the fibre on the root systems, in fact, existed. In those root systems in which the fibre was concentrated on the upper part of the main framework, where the roots were removed in their entirety, the proportion of fibre should have been approximately one-half that found in the case of the root systems only one-half of which had been recovered. Where the fibre was distributed evenly through the whole system, the relation between the weight of the coarse root and that of the fibre should not have been materially affected whether the entire root system or only a portion of it had been recovered.

TABLE SHOWING ANALYSIS OF ROOT SYSTEMS.

Root-stock.	Excavated.		Excavated.	Dug up.	Excavated.	Dug up.	Differ-ence.	Fibre on stock stem as a % of total weight of fibre.
	Weight of roots as a % of total weight of tree.	Average spread of roots, cm.	Weight of fibre as a % of total weight of roots.	Weight of fibre as a % of total weight of roots.	Weight of fibre per gramme of coarse root.	Weight of fibre per gramme of coarse root.		
108	26·4	212	7·8	17·6	0·09	0·20	0·11	11·10
99	32·0	162	8·2	14·3	0·09	0·17	0·08	13·50
VII	33·8	205	12·8	21·3	0·15	0·27	0·12	4·15
IX	26·1	192	8·7	14·9	0·10	0·18	0·08	11·90
29	33·4	258	6·6	11·2	0·07	0·13	0·06	12·80
9	30·0	268	18·5	28·6	0·23	0·41	0·18	—
45	33·2	193	11·0	17·6	0·12	0·22	0·10	17·70
125	29·9	334	14·8	18·0	0·18	0·22	0·04	—
128	30·7	285	15·2	17·7	0·18	0·21	0·03	6·83
90	29·7	224	7·8	8·1	0·09	0·09	—	7·23
112	30·3	284	17·3	15·9	0·21	0·19	0·02	12·10

In the table, columns 6 and 7, the weight of fibre per gramme of coarse root has been calculated on trees removed by the two different methods. In the case of the trees on seven of the rootstocks, including Malling Nos. VII and IX, when the root systems were excavated in their entirety, the weight of fibre per gramme of coarse root was only about one-half that found in the root systems of the trees on the same rootstocks of which only approximately one-half had been recovered. In the remaining four rootstocks, the amount of fibre to each gramme of coarse root was roughly the same in the two sets of trees. A comparison of figures in columns 4 and 5 yields precisely the same result, although in this case the weight of fibre was expressed as a percentage of the total weight of roots in the two sets of trees. The actual weight of the fibre borne directly on the stock stem was ascertained and is shown as a percentage of the total weight of the fibre, in column 9. Although on the trees on certain of the rootstocks it forms a by no means negligible proportion of the total fibre, since the trees on No. 112, in which the fibre on the root systems was evenly distributed, had as large a quantity of fibre on the stock stem, as had the trees on Nos. 108, 99, 29 or Malling No. IX, in which the fibre was concentrated in the upper part of the root system, there can be no question of its having affected the results described above.

With respect both to the relative amount and the distribution of the fibre on the root systems of the trees growing on this series of rootstocks, it has been possible to demonstrate significant differences. These can be seen in Figs. 1, 2, 3 and 4. The results of these observations supply a striking confirmation of observations which the writer made on the root systems of one-year-old unworked seedlings from crosses between many of the Malling selections of the "Paradise" rootstocks (4). Precisely similar variations in the amount and distribution of the fibre on these root systems were observed. It is of interest to find that such morphological differences can still be discerned on worked trees, after several years, in spite of the intervening process by which the original seedling was multiplied by the processes of vegetative propagation and the primary seedling root system replaced by a system of purely adventitious origin. A similar example of variation in the relative amount of fibre on the root systems of three-year-old trees of Lane's Prince Albert, on two different vegetatively raised rootstocks, has been reported on elsewhere (5). These differences were undoubtedly of genetic origin. Although the number of individual rootstocks which it was possible to study was limited, the data from them do not suggest that the factors responsible for controlling the relative amount of fibre were associated in any way with those controlling its distribution, nor can any evidence be found of any linkage between these root characters and those associated with the rootstock's potentialities as manifested in their influence on scion behaviour. Neither does there appear to be any ground for supposing that these differences in the quantity and distribution of the fibre on the root systems of these rootstocks, have exercised any purely physical influence on the relative vigour, productivity or other characters of the trees with which they have been associated.

The writer's thanks are due to Mr. W. S. Rogers for his advice in carrying out this work, to various members of the recording staff for their assistance, and to Miss K. Cornford for taking the photographs.

Summary.

This paper describes the results of an analysis of the root systems of four-year-old trees of Lane's Prince Albert on nine rootstocks raised from seed from a cross between Malling No. VIII × Malling No. IX.

Wide differences were found in the relative amount of fibre on these root systems and in its distribution on the framework of main roots. Where the entire root systems were excavated, the weight of the fibre was found to comprise 6·6 per cent. of the weight of the entire root system in trees on seedling No. 29 while it comprised 18·5 per cent. of the total root weight in trees on seedling No. 9.

Although a direct measure of the distribution of the fibre on these root systems was not possible, it is shown, by a comparison of trees dug up by different methods, that, in trees on five of them, the fibre was concentrated in the upper part of the system. The fibre was distributed evenly over the whole root system in the trees on the remaining four rootstocks.

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FIG. 1

Root System of Lane's Prince Albert on No. 9. (Four-year-old tree.) Much fibre chiefly in upper part of system.

FIG. 2

Root System of Lane's Prince Albert on No. 112. (Four-year-old tree.) Much fibre evenly distributed throughout system

FIG. 3

Root System of Lane's Prince Albert on No. 108. (Four-year-old tree.) Little fibre chiefly on upper part of system.

FIG. 4

Root System of Lane's Prince Albert on No. 99. (Four-year-old tree.) Little fibre, evenly distributed throughout system.

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EXPERIMENTS ON HASTENING THE FRUITING OF SEEDLING APPLES

By H. M. TYDEMAN

All those engaged in breeding new varieties of fruits are familiar with the fact that fruit trees raised from seed are often extremely slow in coming into bearing. Whereas it is not unusual to obtain some fruit from trees propagated from established varieties, upon suitable rootstocks, during their first few years, it may take up to ten years or even longer to obtain fruit from seedlings growing upon their own roots. The trees frequently bear short, sharp, spiny growths and narrow, elongated leaves during this early unproductive period but the growth gradually becomes more normal as the trees begin to come into bearing.

The discovery of methods whereby the fruiting of seedling trees can be hastened has engaged the attention of those interested in the improvement of cultivated fruit trees, from the very earliest times. We are told that Theophrastus (370-285 B.C.), the pupil of Aristotle, was perfectly familiar with the advantages of grafting for the amelioration of seedling fruit trees while Virgil (80 B.C.), the Roman poet, summarizes the problem and suggests a remedy in the Georgics.

> " But slowly comes the tree which thou has sown,
> A canopy for grandsons of thine own."
>
> (Geor. ii.)

> " Apple trees grafted with the tender shoot
> Quickly gain strength and bear superior fruit."
>
> (Geor. ii.)

Loudon (1) says, " the Romans were aware of all our common, and some of our uncommon, practices. They . . . even made incisions and ringed trees to induce fruitfulness." The practice of grafting wildings into cultivated olive trees appears to have been common with the Hebrew husbandman in Biblical times.*

In more modern times (1672), Francis Drope (2) offers an ingenious explanation of the effect of grafting in improving seedling fruit trees. He says, " This likewise is the reason why such trees are more busied in bringing forth branches and are more subject to cankers than others ; for having taken from the Earth at the first for the most part a growing nourishment, they have no other place, nor stop in its passage, through which it might be percolated, and where it might deposit its corrosive humour ; which does not prove so in the sower stock, where there are enemies enough to encounter and subdue it into a better temper."

De La Quintinye (3) in 1693 thus described the practice of overworking to produce early fruits on seedlings : " Nothing is so common in our *Gardens* as to *Graff* in Slits upon Old *Trees* be it either to be rid of some ill *Fruit* we are weary of, or to improve some considerable Novelty that has been discovered."

" A Lover of Planting " (4) writing in 1685, suggests a rather different method. He says : " And this inconvenience is always found in Trees coming of Seed and not grafted or inoculated. That they are very long before they bear Fruit, whereas stocks

* Perhaps the clearest allusion to the practice is that which occurs in Romans xi., verse 17, but the implication of verse 24 is equally unmistakable.

grafted or inoculated from Trees which experience assures are of good bearing kinds and Fruits, commonly bear well in three or four years, and so continue. If you would have some Trees raised of the seeds of Apple kernel, view your Seminary about Michaelmas and see which of your seedlings has produced the broadest, fairest and largest Leaf and Shoot and these elect for your Trees to be set without Grafting, for it's commonly observed that those seed plants that have very large, fair and broad leaves, bear the fairest and largest fruits."

John Evelyn (5), in 1776, advocates transplanting. "Since", he says, "as there is something in super graffing, or the repetition of graffing, for the enlargement or melioration of fruit so there may be also in a careful removal . . . and likewise because it is presumed that most trees propagated by seeds, emit a principal root very deep into the earth, which frequently extracting but a coarser nutriment (though it may haply yield a close and firmer timber) is not yet so apt to shoot and spread as what are by removal deprived of that root."

A form of summer pruning appears to have been the principal resource of Henry van Oosten, the Leyden gardener, whose book, according to Noehden (6) appeared in 1711, translated from the Dutch into English. His methods included frequent transplanting, and the boring of a hole in the tree into which an oaken plug was driven. "But as the most effectual", says Noehden, "he considers the repeated pruning of the tree, in summer, by which, as it causes the tree to bleed, the current of sap is naturally weakened . . . in practising it from the month of April, when already much of the sap has been wasted, you tame the luxuriance of the tree, by the wounds you inflict. He rests upon the idea that a superfluity of sap produces nothing but twigs and moderate sap produces fruit."

It would seem, therefore, that, from the earliest times, the treatment of seedling fruit trees to induce early fruiting has been based on : (*a*) The supposed ameliorating influence of working the seedling on to a rootstock although there appears to have been no very clear idea of the exact function of the rootstock. The couplet of Alexander Pope :

> "As fruits ungrateful to the planter's care,
> On savage stocks inserted, learn to bear"

would suggest that in his day the rootstocks used may have been wild crabs. The fact that different rootstocks might exert a different influence on the precocity of the seedling scion does not appear to have been appreciated.

(*b*) The overworking of the seedlings on to mature bearing trees.

(*c*) Root pruning and frequent transplanting founded on the belief that the deeper the roots were allowed to penetrate into the soil, the coarser the nourishment they would obtain and the more vigorous and unproductive the growth they would make.

(*d*) Branch pruning, more particularly in summer, from its weakening effect on the tree, due, it was thought, to the bleeding of the sap.

(*e*) The driving of an oaken plug into the trunk of the tree. It is a little difficult to discover the underlying philosophy upon which this practice was based. It may possibly have been a degeneration of the unquestionably ancient practice of ringing. Hedrick (7) says : "Thus, whenever the discourse turns to pears, from Diophanes, who lived in Asia Minor a century before Christ, down through the ages, in Greece, Italy, France, Belgium, to the eighteenth century in England, runs the superstition, with various modifications, that to grow the best pears, you must bore a hole through the trunk at the ground and drive in a plug of oak or beech over which the earth must be drawn."

In quite recent times the problem has been studied by a number of workers. Durham (8) discusses cultural methods including the continual grafting and regrafting of the seedling upon itself, said to have been one of the methods of van Mons, the Belgian pear breeder, the stimulation of stipulary buds by various methods of summer pruning, and the bending of branches. Crane (9) working with plum seedlings found that practices, which restricted growth, shortened the juvenile period, although seedlings budded on to rootstocks or grown with their roots restricted in pots did not come into fruiting any earlier than similar unworked trees grown in the open ground. Spinks (10) on the other hand, concludes that any treatment which restricts growth, such as ringing, root pruning, growing the seedlings in pots, or working them on dwarfing rootstocks, tends to prolong the " juvenile " period. Ballard (11) has reported good results from ringing seedling apples and pears, but found that they fruited almost as quickly on their own roots as when overworked on to older trees.

Experiments at East Malling.

(*a*) *On the use of rootstocks.*

Experiments on the effect of rootstocks in hastening the fruiting of seedling apples have been carried out at East Malling since 1921.

In a preliminary trial between 1921 and 1928, in which seedlings were grown on the dwarfing rootstocks Malling Nos. VIII and IX, and the vigorous rootstocks Nos. X and XIII, seventeen out of the thirty-four trees on the dwarfing rootstocks blossomed during their seventh year and only three out of the thirty-four trees on the vigorous rootstocks (12). The seedlings growing upon their own roots were not included in the experiment.

An attempt to confirm this result has been made with a series of seedlings from crosses made in 1929. The crosses were :

Mackintosh Red × Worcester Pearmain.
Mackintosh Red × Beauty of Bath.
Delicious × Cox's Orange Pippin.
D'Arcy Spice × Cox's Orange Pippin.
Bascombe's Mystery × Cox's Orange Pippin.
Rome Beauty × Worcester Pearmain.

Buds from each seedling were worked on to the dwarfing rootstock No. IX and the vigorous No. XII in the autumn of 1930, and these trees were grown with the seedling upon its own roots. A number of seedlings were also worked on to No. II, a rootstock of medium vigour. The trees were grown at about 2 feet 6 inches apart in rows six feet apart and were trained to wires. Although certain differential pruning treatments were introduced on a few duplicate trees, the data on the effect of rootstock, which is shown in Table I, is based throughout on the performance of trees which were entirely unpruned.

It is quite evident from Table I that the use of the dwarfing rootstock No. IX has very appreciably shortened the " juvenile " period of these seedlings. Of the seventeen trees on No. IX, five blossomed in their fourth year from the bud (fifth year from the seed), and eleven blossomed during their fifth and sixth year. Only one of the seventeen trees on No. XII flowered at five years from the bud, and in the following year, a few blossoms were recorded on two of the seventeen seedlings growing on their own roots. There seems no reason to doubt that, under the conditions here, a dwarfing and precocious rootstock, such as Malling No. IX, does appreciably hasten the blossoming and

Table I.

Effect of the Rootstock on the Blossoming of Seedling Apples.

Parents.	Number of seedlings.	Rootstock.	At five years from seed.		At six years from seed.		At seven years from seed.	
			Number of trees which flowered.	Average number of blossom trusses per tree.	Number of trees which flowered.	Average number of blossom trusses per tree.	Number of trees which flowered.	Average number of blossom trusses per tree.
Mackintosh Red × Worcester Pearmain..	7	Own roots	0	0	0	0	0	0
		No. IX	1	19·0	5	10·0	5	33·4
		No. XII	0	0	1	5·0	0	0
Mackintosh Red × Beauty of Bath ..	5	Own roots	0	0	0	0	0	0
		No. IX	3	4·3	3	12·3	4	36·0
		No. XII	0	0	0	0	0	0
Rome Beauty × Worcester Pearmain..	2	Own roots	0	0	0	0	2	3·0
		No. IX	1	6·0	2	3·0	1	25·0
		No. XII	0	0	0	0	0	0
Delicious × Cox's Orange Pippin ..	2	Own roots	0	0	0	0	0	0
		No. IX	0	0	0	0	1	1·0
		No. XII	0	0	0	0	0	0
Bascombe's Mystery × Cox's Orange Pippin..	1	Own roots	0	0	0	0	0	0
		No. IX	0	0	1	1·0	0	0
		No. XII	0	0	0	0	0	0

TABLE II.

AVERAGE DIAMETER OF STEM IN CM. AT SIX YEARS FROM THE SEED.

Parents.	Number of seedlings.	On own roots.	On No. IX.	On No. XII.	Number of seedlings.	On own roots.	On No. II.
Mackintosh Red × Worcester Pearmain	7	2·98	3·23	4·85	10	2·78	4·87
Mackintosh Red × Beauty of Bath	5	3·18	3·81	4·71	4	2·57	4·71
Delicious × Cox's Orange Pippin	2	3·93	3·30	4·41	2	2·23	4·38
Rome Beauty × Worcester Pearmain	2	4·90	3·88	4·58			
Bascombe's Mystery × Cox's Orange Pippin	1	2·72	2·40	3·49	2	1·86	4·07
D'Arcy Spice × Cox's Orange Pippin					1	1·32	2·96

fruiting of seedling apples. Of nineteen seedlings growing upon their own roots and upon No. II, seven of the trees upon No. II blossomed during the spring of 1936, their seventh year from the seed, but none upon their own roots.

That early fruiting is not entirely associated with reduced vigour, as has been supposed by some early writers on the subject, can be shown by a comparison of the relative stem diameters of the trees on their own roots and on rootstocks, in this trial. These are summarized in Table II and show that, in all but a few cases, the trees growing upon their own roots were less vigorous, measured in this way, than were the trees on No. IX. It is interesting to notice that in the only case in which the seedlings on their own roots were stouter than the trees on either No. IX or No. XII (Rome Beauty × Worcester Pearmain), both of them blossomed in their seventh year.

(*b*) *On the effect of winter pruning.*

Although it was never intended to make pruning a main issue in these experiments, there were a number of duplicate trees upon all the rootstocks which it was decided to utilize to test the effect of drastic spur pruning and the shortening of the leader in winter. Three treatments were tried, the tipping of the leaders to one-half their length with and without spur pruning to four buds, and spur pruning without leader tipping, in comparison with unpruned trees. In most cases there were only two trees of any seedling upon one rootstock and it was usually only possible to compare the effect of a single method of pruning with the unpruned trees. The blossoms borne during the spring of 1936 (the seventh year from the seed) by the trees subjected to these methods of pruning are shown in Table III. They indicate very clearly that all the methods of winter pruning tried have delayed blossoming. Of the thirty-seven unpruned trees, sixteen were in blossom at seven years from the seed, of the fifteen trees spurred but not leader tipped, only one had blossomed ; of eighteen trees leader tipped and spurred, only one had blossomed, while only three of the fifteen trees, leader tipped but not spurred, had blossomed. At the same time there was a considerable reduction in the number of blossom trusses borne

Table III.

Effect of Pruning on Blossoming at Seven Years from the Seed on Rootstocks Nos. IX and II.

Parents.	Number of seedlings.	Pruning Treatment.							
		A		B		C		D	
		Number of trees which blossomed.	Average number of blossom trusses per tree.	Number of trees which blossomed.	Average number of blossom trusses per tree.	Number of trees which blossomed.	Average number of blossom trusses per tree.	Number of trees which blossomed.	Average number of blossom trusses per tree.
Mackintosh Red × Worcester Pearmain ..	2	1	1	0	0	0	0		
	1	0	0			0	0	0	0
	2	1	92	1	8				
	6	2	106			1	12		
	6	4	25					2	11
Mackintosh Red × Beauty of Bath ..	2	2	6	0	0				
	1	0	0			0	0		
	2	2	26					1	10
Delicious × Cox's Orange Pippin ..	1	1	1	0	0	0	0		
	1	1	1	0	0				
Bascombe's Mystery × Cox's Orange Pippin	4	0	0	0	0	0	0		
	2	1	1	0	0			0	0
	1	0	0			0	0	0	0
	1	0	0	0	0				
	2	0	0			0	0		
	3	1	1					0	0

The treatments were :—

A Entirely unpruned.
B Leaders left full length, all laterals shortened to 4 buds.
C Leaders cut back one-half, all laterals shortened to 4 buds.
D Leaders cut back one-half, all laterals left full length.

by the trees which flowered where they had been subjected to any form of winter pruning. While a pronounced effect in retarding blossoming as the result of drastic spur pruning was to have been expected, it is a little surprising to find that the shortening of the leader, without spur pruning, should have had so marked an effect on the fifteen trees available for this treatment.

(*c*) *On the effect of overworking on to a mature tree.*

An experiment on the effect of overworking scions from seedlings on to a mature bearing tree was carried out during 1932 to 1935. Twenty scions, two from each of ten seedlings raised from seed in 1930, were cleft grafted on to a sixteen-year-old tree of Lane's Prince Albert, in full bearing, during the spring of 1932. All the scions were successfully united and made very vigorous growth during the following years. They showed all the usual signs of " juvenile " growth and were markedly " spiny ". Although the remaining branches of Lane's Prince Albert blossomed profusely during each year, the seedling scions remained completely barren until the spring of 1935, when two of them, taken from different seedlings, bore a single truss of blossom. Unfortunately, the experiment was somewhat cut across by the fact that the tree upon which the seedlings were growing had to be transplanted during the winter of 1934-5. Although the blossoms which developed during the following spring must have been present in embryo before the removal of the tree which cannot, therefore, have affected the result, it was impossible to pursue the experiment further. As far as the available information goes, it does not suggest that overworking apple seedlings on to a mature tree has appreciably hastened their blossoming. Although two of the scions were only three years old when they began to flower, they were actually five years from the seed. At this age it has been possible to obtain blossoms upon seedlings worked on to a dwarfing rootstock.

(*d*) *On the effect of root restriction.*

In order to test the effect of restricting the root systems, one hundred seedlings, raised from seed in 1930, were grown on their own roots in pots. Care was taken to ensure that the seedlings did not root through the pots which were kept as small as possible. One-half of the seedlings were grown under glass, in an orchard house, on a floor of ashes and the remainder were grown out-of-doors plunged into the soil. The set of trees kept under glass made better growth almost from the commencement, and by the end of five years were almost twice as large as those growing out-of-doors. The average diameter of the stems of the trees in the two sets at the end of their fifth year was as follows :—

Under glass	.. ..	1·80 cm.
Out-of-doors	.. ..	1·55 cm.

The growth of all the trees was markedly " juvenile " throughout and it was not until the spring of 1936, at six years from the seed, that blossoms were recorded upon five trees, three in the set kept under glass, and two in the set kept out-of-doors. Unworked seedlings from the same families, and raised in the same year, growing in the open ground, had not blossomed by that time and it seems likely, therefore, that root restriction did accelerate the blossoming of these seedlings to some extent. Upon the other hand, the method is, obviously, no more speedy than that of growing the seedlings upon dwarfing rootstocks.

All the evidence so far collected here, seems to point to the use of a dwarfing rootstock, such as Malling No. IX, as the surest method of hastening the fruiting of seedling apples. Any form of winter pruning appeared definitely to retard blossoming

while the practice of overworking the seedlings on to established varieties, widely recommended since the time of De La Quintinye, did not appear to effect any marked acceleration of blossoming in these experiments. Restricting their roots in pots brought unworked seedlings into blossom more quickly than was the case with similar trees growing under normal conditions in the open ground, but there seems no reason to think that they would not have blossomed quite as quickly if grown upon dwarfing rootstocks.

Summary.

This paper describes attempts to hasten the fruiting of seedling apples by the use of dwarfing rootstocks, winter pruning, overworking on to mature trees and restricting the root systems by growing the seedlings in pots.

It was found that seedlings worked on to the dwarfing rootstock, Malling No. IX, came into blossom more quickly than when they were worked on to the vigorous Malling No. XII, or grown upon their own roots.

Shortening the leading shoot or spur pruning, either together or separately, retarded blossoming. Unpruned trees blossomed more quickly and more profusely.

Overworking seedling scions on to a mature cropping tree of an established variety did not have any very marked effect in hastening blossoming, since, although two of the seedling scions had some blossoms at three years from the date of grafting, the seedlings from which they were taken were then five years old.

Unworked seedlings grown with their roots restricted in pots, blossomed more quickly than seedlings of the same age and from the same crosses, growing on their own roots out-of-doors, but the method appeared to be less effective in inducing early blossoming than growing the seedlings upon a dwarfing rootstock.

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NEW VARIETIES OF ROOTSTOCK FOR PLUMS

II. A FINAL REPORT ON SEEDLINGS OF *PRUNUS DIVARICATA*

By H. M. TYDEMAN

During the latter part of 1931 approximately 150 plum rootstocks raised from seed collected from thirty wild parent trees growing in various localities in Eastern Georgia, Armenia, Black Sea Region, Northern Caucasus, etc., were sent from the John Innes Horticultural Institution, in the hope that they might be of interest to this Station as possible rootstocks for plums. Although they were received at Merton under the name *Prunus divaricata*, a comparison of their botanical characters early established the fact that they were similar in all essential respects with varieties of Myrobolan (*Prunus cerasifera*). The four East Malling types of Myrobolan were selected from a quantity of seedlings received from France. They differed most distinctively in the colour of the young wood and the shape, pose and colour of the leaves. Hatton's (1) description of these four characters is shown at the top of Table I, together with similar descriptions of twenty-nine single tree selections of these so-called *Prunus divaricata* seedlings. There was a certain amount of variation among the progeny from any one wild parent and the description given is that of the majority of the seedlings. Although selections resembling the East Malling types very closely were found with comparative frequency, only rarely were they apparently identical in their botanical characters. 273/18255 from Eastern Georgia, and 545/32502 from Armenia, resembled Myrobolan C very closely. Six of the eight selections from Armenia and one from each of Ajaristan, North Caucasus, Black Sea Region, and Nagorni, Karadah, were all very similar botanically to Myrobolan A. But for the fact that their leaves were of a darker colour the 369/33253 seedlings bore a close resemblance to Myrobolan D. The pale leaved types, Myrobolan B and D, were not observed at all among these seedlings, although seven of the selections had the greenish wood colour of Myrobolan B, and ten the drooping leaves of Myrobolan D. In general the seedlings from any one geographical region showed wide variation. Five distinct types occurred among the eight selections from Armenia, while of the four selections from Eastern Georgia all differed in one or other of the four characters described. Variation could also be seen among the three selections from Abhasia and the three from Ajaristan. On the other hand, the three selections from Dagestan were apparently all identical with respect to their vegetative characters.

The individual seedlings were planted out in nursery rows and were budded with the variety Czar during the summer of 1932, both because it so commonly exhibits the phenomenon of " incompatibility " with the rootstocks upon which it is worked and also because it has proved a good indicator of rootstock effect. In order to make it possible to discriminate between casual bud failures due to manipulative and other causes and true incompatibility between the bud and its rootstock, wherever possible at least two buds were inserted into each seedling. Since all the buds were allowed to grow unchecked during their first year, a differential element was introduced into the trial which probably has affected their subsequent behaviour to some extent. After the first year, the trees were reduced to a single stem but were otherwise left unpruned. They were never

Table I.

Botanical Characters of *Prunus divaricata* Seedlings compared with Four Malling Selected Myrobolans.

Selection number.	Locality from which collected.	Colour of the wood.	Shape of the leaves.	Pose of the leaves.	Colour of the leaves.
Myrobolan A	East Malling selection	Reddish purple	Ovate lanceolate	Apex drooping	Dark green
Myrobolan B	,, ,,	Green to brownish purple	Oblong lanceolate	Held horizontally	Light green
Myrobolan C	,, ,,	Dark purple	Broadly elliptical	Apex drooping	Dark green
Myrobolan D	,, ,,	Deep purple	Ovate to elliptical	Drooping	Yellow green
273/18255	Eastern Georgia	Dark purple	Broadly elliptical	Apex drooping	Dark green
221/18119	,, ,,	Green to brownish purple	Oval	Apex drooping	Dark green
350/33086	,, ,,	Green to brownish purple	Ovate to elliptical	Apex drooping	Dark green
369/33253	,, ,,	Dark purple	Ovate to elliptical	Drooping	Dark green
167/32410	Armenia	Green to brownish purple	Ovate to elliptical	Drooping	Dark green
214/32449	,,	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
484/32303	,,	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
545/32502	,,	Dark purple	Ovate to elliptical	Apex drooping	Dark green
35/32484	,,	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
350/32478	,,	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
77/32191	,,	Reddish purple	Elliptical	Apex drooping	Dark green
145/32111	,,	Reddish purple	Elliptical	Drooping	Dark green
247/18808	Abhasia	Green to brownish purple	Ovate to elliptical	Apex drooping	Dark green
202/17998	,,	Reddish purple	Oval	Drooping	Dark green
63/18794	,,	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
265/32972	Ajaristan	Reddish purple	Ovate to elliptical	Drooping	Dark green
144/33057	,,	Reddish purple	Oval	Apex drooping	Dark green
243/32219	,,	Reddish purple	Elliptical	Apex drooping	Dark green
3/32508	Azerbeijan	Reddish purple	Oval	Drooping	Dark green
57/32040	,,	Green to brownish purple	Ovate to elliptical	Drooping	Dark green
15/33315	Dagestan	Reddish purple	Oval	Drooping	Dark green
22/33558	,,	Reddish purple	Oval	Drooping	Dark green
2/33302	,,	Reddish purple	Oval	Drooping	Dark green
109/33582	South Dagestan	Reddish purple	Elliptical	Apex drooping	Dark green
66/32698	Northern Caucasus	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
157/33381	Black Sea Region	Reddish purple	Ovate to elliptical	Apex drooping	Dark green
36/32569	Near Vladikarkaz	Green to brownish purple	Ovate to elliptical	Apex drooping	Dark green
393/32240	Nagorni, Karadah	Reddish purple	Elliptical	Apex drooping	Dark green
33/33472	Kuban, Maikop	Green to brownish purple	Ovate to elliptical	Apex drooping	Dark green

removed from the nursery rows in which they were worked and it was, therefore, found impossible, owing to their crowded condition, to continue the trial beyond the fourth year. A preliminary report on the trial has already been published (2).

As Table II shows, Czar failed to " take " at all with a number of these seedlings. While this result might possibly have been attributable to other causes, it strongly suggests that at least some of these seedlings may have been definitely incompatible

Table II.

Behaviour of Czar Plum on Thirty *Prunus divaricata* Selections.

Rootstock selection number.	Number of seedlings.	Number of buds inserted.	Number of seedlings which failed to take the bud.	Number of trees which died subsequently.	Average weight of tree at four years old lb.	Average wood growth, three years' total, cm.	Average diameter of stem at 3 in. above union, cm.	Average number of blossom buds per tree, four years' total.	Average number of fruits per tree, four years' total.
15/33315	6	13	1	3	7·6	1341	2·89	226	15·0
484/32303	7	14	0	0	5·0	1445	2·52	342	9·4
343/32219	4	10	0	0	6·6	1588	2·62	121	3·0
350/32478	4	8	0	0	8·6	1591	2·45	208	11·3
214/32449	5	13	0	1	6·4	1740	2·87	247	18·8
167/32410	6	15	0	0	7·3	1794	2·79	198	10·2
109/33582	5	10	0	0	7·8	1844	3·06	269	14·2
145/32111	4	8	0	0	6·6	1865	2·74	276	2·9
221/18119	3	6	0	0	8·0	1873	3·19	261	8·1
393/32240	4	9	0	0	7·8	1882	2·77	130	4·2
57/32040	8	19	1	1	8·9	1948	3·14	321	11·7
545/32502	7	15	1	0	8·2	1970	2·89	273	12·7
E/205	7	15	0	0	10·7	2076	—	49	5·3
66/32698	4	9	0	0	9·1	2119	2·93	102	23·0
22/33558	6	13	0	0	9·0	2233	3·05	242	6·0
369/33253	3	6	0	0	8·7	2261	3·11	153	8·3
63/18794	4	6	1	0	11·0	2507	3·64	204	15·5
202/17998	5	10	2	0	9·0	2514	3·05	174	23·9
36/32569	6	13	0	0	8·8	2602	3·07	320	38·4
2/33302	8	15	0	3	12·0	2622	3·49	228	27·8
35/32484	5	12	0	0	10·5	2636	3·28	107	4·6
144/33057	4	9	0	0	14·4	2665	3·70	450	20·2
350/33086	2	4	0	0	9·6	2671	3·35	102	6·5
157/33381	8	18	1	0	11·7	2858	3·39	400	21·3
77/32191	4	7	1	0	11·8	2969	3·42	389	18·6
273/18255	5	11	0	0	11·4	3010	3·34	142	7·3
33/33472	4	9	0	1	9·6	3048	3·66	429	13·0
247/18808	7	14	2	0	13·9	3049	3·67	223	11·4
3/32508	3	8	0	0	13·2	3087	3·36	198	2·1
265/32972	3	6	0	0	15·4	3522	3·92	102	3·6

with the variety Czar. If this was so it is somewhat surprising since Czar upon *P. cerasifera* (Myrobolan) is usually considered a safe combination. However, in the case of ten of them, it was impossible to get the buds to grow at all, while nine trees broke out at the union subsequently. It looks, therefore, as though something like 12 per cent. of these seedlings were apparently "incompatible" with Czar. Since the chromosome number of all the seedlings was thought, by the workers at Merton, to have been the same ($2n = 16$), if they really differed in their compatibility with Czar it strongly supports the view that the phenomenon of "incompatibility" is not directly brought about by differences in chromosome number nor, presumably, in chromosome size; between the rootstock and its scion. It is interesting to notice that of the nine trees which died after the buds had grown away healthily, six, three on 15/33315 and three on 2/33302, were from Dagestan.

As will be seen from Table II, where the trees on each seedling group are arranged in the ascending order of their mean wood growth, the range of variation both for vigour and productivity, between the trees upon the different selections was fairly wide. At

four years old they ranged in weight from 5 lb. to 15·4 lb. and in the total length of new wood growth made to the end of their third year, from 1,341 cm. to 3,522 cm. The correlation between length of new wood growth and the weight of the tree was not always particularly close. This may possibly have been due to differences in the relative stoutness of the wood, or it might be accounted for by variations in the relative size of the root systems, although they were dug up as uniformly as possible and no very obvious differences between them could be seen. Although the trees were unquestionably treated in a differential manner at the end of their first season, when those which had developed from more than one bud were cut back to a single stem, it does not seem likely that this would have permanently affected the relation between the wood growth and weight of the trees and, moreover, since the figures in Table II are based on the average of several trees, not all of which were treated alike in this respect, such differences, had they existed, would hardly have been so marked.

There were seventeen trees of Czar on layered Damas C growing in this trial. At the end of their fourth year they weighed on the average 12·3 lb. per tree, and were thus heavier than all but four of these seedling families. They made less wood growth, however, up to the end of their third year, than the trees on twelve of the selections. Since Hatton (3) finds Damas C a much less vigorous rootstock than Myrobolan B, when worked with Czar, it seems unlikely that more than a few, if any, of these *P. divaricata* selections were as vigorous with Czar as Myrobolan B.

These rootstocks appear to have exerted very different influences upon the productivity of the scion, whether it is expressed in terms of the blossoms produced or of actual fruit production. Thus, the trees on 144/33057, one of the more vigorous of these selections, produced, on the average, almost ten times as many blossoms in the four years as did those on E/205, a somewhat less vigorous selection. The trees on 36/32569 bore more than eighteen times the quantity of fruit borne by the trees on 3/32508, although the latter made considerably more vigorous trees. The seventeen trees on Damas C growing on the same plot produced slightly more blossoms in the four years than those on any of these selections. The trees on only one selection, 36/32569, of about equal vigour with those on Damas C, produced a greater number of fruits in the four years. Since Czar on Damas C has been found to produce rather less fruit over its first nine years than on Myrobolan B, it seems fairly certain that these single tree progenies were less productive during their earlier years than Myrobolan B, with this variety.

Apart from the very striking variation between the different single tree selections, there was considerable variation between the trees growing on the seedlings within each selection, although this was not markedly greater than that between the trees on the layered Damas C rootstocks. For example, the five trees on 273/18255, a selection which botanically was very similar to Myrobolan C, varied in the length of wood growth made during 1935 from 649 to 1,382 cm. while the trees on Damas C varied from 268 to 1,500 cm. The variation in blossom production during 1936 was again greater among the trees on the layered Damas rootstocks than in this *P. divaricata* selection—from 33 to 282 blossoms in the former case and from 44 to 113 in the latter. While the trees on Damas C bore from 9 to 53 fruits during 1936, those on the 273/18255 seedlings produced from 2 to 19 fruits, a much narrower range. It was noted that the fruits were very uneven in their time of ripening upon these selections. Although purely environmental factors were unquestionably responsible for a large part of the variation which was recorded there is no evidence that they exercised a differential effect in favour of any particular group of seedlings. Although they were not randomized in any way, "buffer" trees were grown at the ends of the rows where the trees might have been expected to have

grown more vigorously. Actually trees on groups of seedlings varying widely in their vigour and productivity were frequently growing side by side.

The seedling Myrobolans which have been tried at East Malling have always been found to be very uniform in their behaviour and it is, therefore, somewhat surprising to find that these seedlings have shown so wide a range of variation in their influence upon the scion variety. Although the variation within any one of the single tree progenies does not appear to be much greater than that between layered rootstocks of Damas C, the different selections have shown unexpectedly wide differences in vigour and productivity, but few, if any, appeared to be as vigorous or as productive, in their early years, as the East Malling selection Myrobolan B. Although there were indications that certain of them might have made useful semi-dwarfing rootstocks, few, if any, of them showed promise of being sufficiently productive in their early years to make them worthy of further trial.

Summary.

An account is given of trials with 150 seedlings collected from thirty wild trees of *Prunus divaricata* growing in various localities in South Eastern Europe and Asia Minor.

Their botanical characters are compared with those of the East Malling selections of Myrobolan and it is shown that, while several were similar in their major particulars to Myrobolan A and C, types with pale green leaves similar to B and D did not occur.

Approximately 12 per cent. of these seedlings failed to make trees when budded with the variety Czar. In the majority of these cases the buds failed to grow at all but in others the trees broke out at the union after growing away healthily. This was thought to be due to incompatibility.

The trees unexpectedly varied between comparatively wide limits in their vigour measured by the total length of new wood growth, the diameter of the stems and the final weight of the tree at four years old.

Wide differences also existed in their relative productivity measured by the number of flowers and fruits produced by the end of their fourth year. Since they were thought to be less productive in their early years than varieties of plum rootstock already in common use they were not considered worthy of further trial.

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SOIL MOISTURE STUDIES

I. WATER UTILIZATION BY APPLE TREES IN CULTIVATED AND GRASS ORCHARD, COMPARED WITH FALLOW LAND

By W. S. ROGERS

In a previous paper (1) data were given concerning seasonal soil moisture variations, as shown by moisture meters, in a grass orchard and a fallow plot in the years 1933, 1934 and 1935. These three years had comparatively dry summers.

The summer of 1936, except for the month of May, was very wet. The rainfall in June and July was 3·95 inches and 2·80 inches respectively. Records obtained in 1936 from the same two plots as in the previous study, with the addition of records from a cultivated apple orchard, are discussed in the paper which follows. Besides showing the contrast between soil moisture in the wet summer of 1936 and the previous dry seasons they throw further light on water utilization by apple trees and grass, and on the relation between soil suction and water intake by the plant.

The moisture meters were of the porous pot type described in other papers (1, 2). These instruments indicate the suction force or "pull" of the soil, which is nil when the soil is saturated and rises as the soil dries. The pull can be expressed in centimetres of mercury, or in terms of the pF values introduced by Dr. Schofield. The pF is the logarithm of the suction force in centimetres of water. The pF values are marked on the graphs, as well as direct suction values in centimetres of mercury, but the latter will be used in the ensuing discussion, as they give a better contrast over the suction range covered by the meter (i.e. 0 to about 65 cm. Hg).

The meters were installed at two depths in each of the three plots under discussion, viz. 12 in. and 36 in. in the grass and the cultivated orchards, and 9 in. and 30 in. in the fallow plot. These depths refer to the middle of the porous pot, whose porous area actually extends about 1 in. above and 1 in. below the depth given.

Soil. The soil on each of the three plots mentioned is a medium loam, with about 1 ft. of darkish top soil passing to lighter compact sandy subsoil, usually to a depth of about 3 ft. A porous rock called Kentish Ragstone underlies this soil, usually with a thin sticky "B horizon" just above it. The top foot contains about 55% coarse and fine sand and 20% fine silt and clay; the subsoil about 65% coarse and fine sand and 20% fine silt and clay; the thin sticky B horizon about 40% coarse and fine sand and 40% fine silt and clay. In the top soil meter pulls of 0, 20, 30 and 60 cm. Hg correspond to soil moisture contents, calculated on dry weight, of approximately 25%, 14%, 12% and 10·5% (2). In the sandier subsoil the curve does not rise quite so steeply, and a pull of 60 cm. represents a moisture content of about 8%. The meters reach the limit of their range between 60 and 65 cm. Hg, so after the meter reaches about 60 cm., we are only able to say that the pull is 60 cm. or more. These points are discussed in other papers (1, 2).

Soil Moisture on Fallow Land.

The daily rainfall at East Malling is shown at the bottom of Fig. 1. Section C shows the "soil pull" read daily at 9 a.m. at 9 in. (solid line) and 30 in. (dotted line) on a

small plot kept clean-cultivated since 1933, three years previously. It will be seen that the maximum dryness of the soil at 9 in. during the year only corresponded to a pull of 25 cm. Hg (pF 2·53). From January to March the soil kept at a pull of about 4 cm. (pF 1·73) with the exception of a few dry days in February. No really marked drying was recorded till May, when the pull gradually rose to 22 cm. This rise was soon checked by further rain. After a further rise during a short dry period in August, the pull fell to only 1 or 2 cm. in a very wet November. In fact the top soil was almost saturated throughout the winter.

The soil at 30 in. showed practically no drying all through the year. As evaporation at the surface had caused very little drying at 30 in. even in very dry years (2), it was hardly to be expected that there would be much water loss at this depth in a wet year. Actually the pull varied from about 4 cm. in the winter to 8 cm. in the drier periods. Even under these relatively moist conditions, not complicated by plant roots, the 21 in. of soil separating the 9 in. and 30 in. meters was sufficient to cause a lag of two or more days before any tendency of the 9 in. meter either to fall or to rise was reflected in a fall or rise of the 30 in. meter. For example, rainfall on 9th and 10th August brought down the pull at 9 in. from 9·3 to 2·5 on 11th. The 30 in. meter at 5·3 did not fall till 13th, and then, although the soil at 9 in. was continuously drying, the 30 in. meter gradually fell to 4·6 cm. on 16th and then remained stationary till 24th, after which it began rising slowly. It is therefore quite clear that both downward and upward movement of water by capillary action is very slow indeed.

The lower layers of soil in this plot have now remained almost saturated for three years, and Horse-tail (*Equisetum*), a well-known indicator of wet land, has sprung up on this plot, while it is not found in any of the plots round. This is an interesting example of the " over-conservation " of water. It cannot be said that the ground has become actually waterlogged, since the Ragstone rock provides a very free-draining base, but it is clear that if soil is allowed to remain at its " field capacity " for a long period it will develop a wet ground flora.

Soil Moisture in Grass Orchard.

In this orchard moisture meters were installed at 12 in. and 36 in. at a distance of 5 ft. from one of the apple trees, a 17-year-old Bramley's Seedling on No. XI rootstock.

The meters were read daily at 9 a.m. omitting Sundays. In the graph Saturday's and Monday's readings are joined by a straight line. During drying conditions this causes practically no inaccuracy. Under wetting conditions, where the meter was high on Saturday morning and low on Monday, one cannot say whether a rapid fall actually occurred on Saturday or on Sunday.

During the winter the soil remained wetted to its field capacity. Drying commenced in April (Fig. 1 (B)), and in May the pull at 12 in. soon exceeded that of the fallow ground at 9 in., showing the action of the tree and grass roots, particularly the latter. The soil at 36 in. also began to dry out (dotted line), showing the drying effect of the tree roots at this depth. The heavy rains of June re-saturated the soil at 1 ft., causing the pull to fall from 60 cm. to 3 cm., but did not penetrate to 36 in., as shown by the continued rise of the 36 in. meter. In a short dry period in August the pull at 12 in. quickly rose to 50 cm. once more, but the September rains checked it again. The heavy rains of October and November brought the soil at 12 in. nearly to saturation from 2nd November onwards, and penetrated to 36 in. on 14th November. The amount of rain falling between 2nd November and 14th November was 3·13 in. The main contrast between the plot in 1936 and the preceding dry seasons was that the soil at 12 in. was

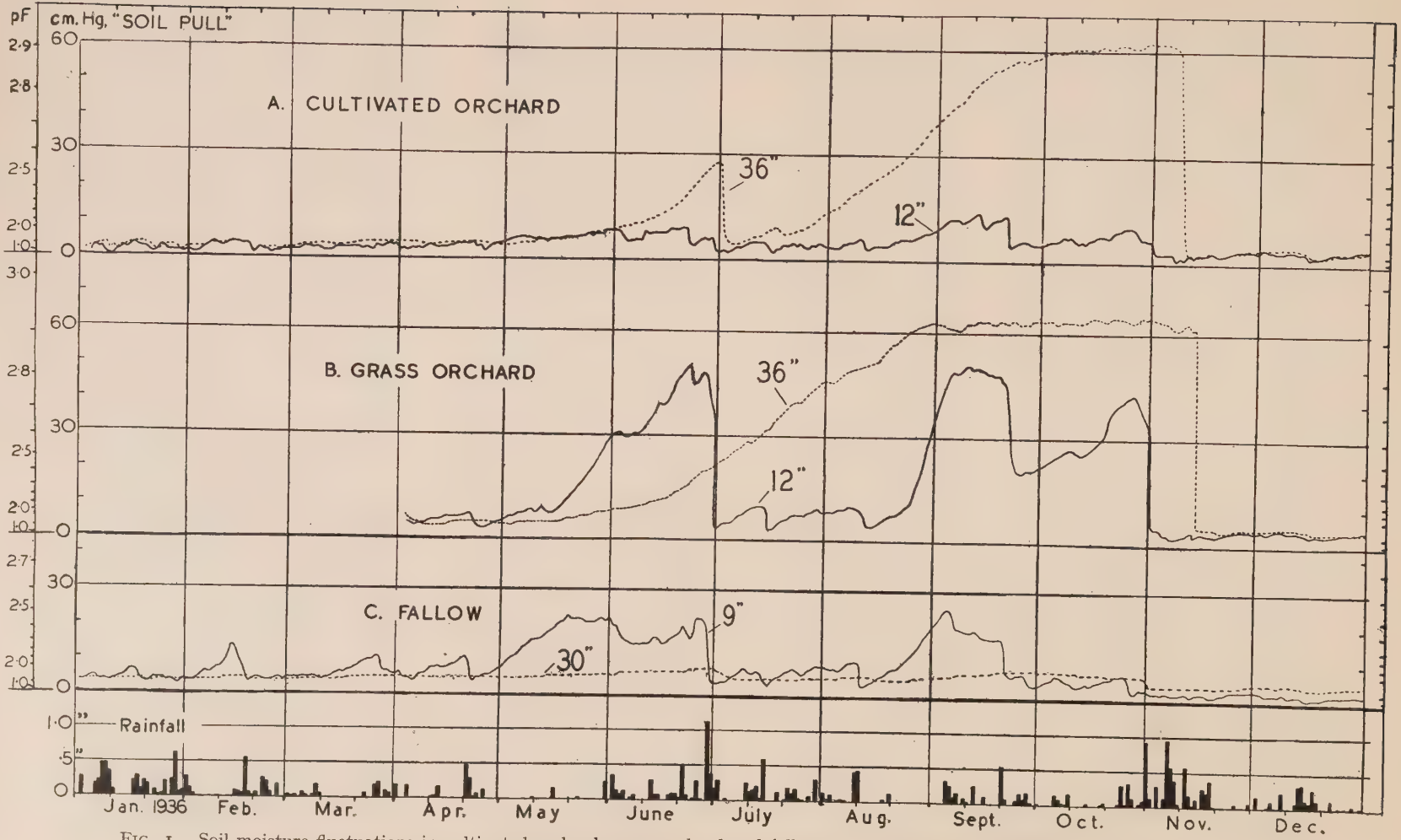

FIG. 1. Soil moisture fluctuations in cultivated orchard, grass orchard and fallow, as shown by the " soil pull ". O equals saturation.

kept at a suction force below 30 cm. in July and August, 1936, while in the two previous years it exceeded 60 cm. in these months (1).

Soil Moisture in a Cultivated Orchard.

The moisture meters in the clean-cultivated orchard were set at a distance of 3 ft. from the trunk of an 18-year-old Lane's Prince Albert apple tree on No. XVI rootstock. This is not quite so large a tree as the Bramley's Seedling in the grass plot, having a trunk girth of 55·0 cm. compared with 60·3 cm. for the Bramley. This tree had a root observation trench beside it, and was not intended for direct comparison with the grass orchard tree. A general comparison of clean cultivated and grass orchard conditions is quite possible, however. The 12 in. meter was connected to a recording vacuum gauge, and so gave a continuous record on a chart. The 36 in. meter was read daily at 9 a.m., excluding Sundays.

The most remarkable point in the soil pull records for this plot (Fig. 1 (A)) is the almost complete absence of drying at 12 in. throughout the year. The heavy rainfalls penetrated through the branches of the tree, and re-moistened the soil at 12 in. as fast as the apple roots used up the water. Slight drying is, of course, recorded in the periods of no rainfall, but the maximum pull of the year is 14 cm. In contrast to this, the pull at 36 in. though reduced from 28 cm. to 4 cm. by rain at the end of June, rose steadily thereafter to over 60 cm. and only fell again on 7th November. In drier summers high pulls have been recorded at 12 in. as well as at 36 in. on this plot.

Discussion.

The fact that there was only one meter at each depth on the various plots enables us to speak definitely of only one position on each plot. The variability of soil moisture within short distances is notorious, particularly under trees, where the rainfall may be shielded, or the root action uneven. However, the meters have the great advantage that each one remains in its identical position all the time, so that the true variation of soil conditions in that position is continuously recorded. In the fallow ground, one meter probably indicates quite well the soil conditions at that depth over the whole area. Under the trees a large series of meters would undoubtedly have given more information, but they were not available. Certain general points show quite clearly from the single examples obtained, and the general correlation is also good.

Conclusions.

An important point shown by these graphs is that under field conditions the soil at different depths can and does remain at widely different suction forces and moisture contents for long periods. For instance all through October the meters at 12 in. and 36 in. in the cultivated orchard showed a difference in pull of more than 50 cm., and in the grass orchard in November the 12 in. and 36 in. meters maintained a difference of over 60 cm. for thirteen days. Further, it is clear that one and the same plant can be drawing water from different soil layers having totally different soil pulls. At first sight it might seem reasonable that if the soil from the surface to 12 in. was nearly saturated and the soil at 36 in. had a pull of nearly 60 cm. the tree would take its water only from the region of lower pull until the whole soil block had come to equilibrium. Graphs A and B show that under these conditions this is not the case. The relatively dry soil at 36 in. continues to get drier, through root action, even while the top 12 in. of soil is nearly saturated.

It is fully borne out that water applied to the surface of a soil block wets it thoroughly to a limited depth, and its further spread is very slow.

One of the most striking contrasts between the three sets of curves is that of the deep meters. On fallow ground, the deep soil remains almost saturated. In grass orchard it dries steadily, even in a rainy summer. In cultivated orchard the drying is not quite so rapid.

In the top soil the rapid use of water by the grass is obvious. The very small drying out at 12 in. in the cultivated orchard is surprising. This is probably due to the wind shielding effect and the shade of the orchard trees, which cut down evaporation.

Acknowledgments.

The writer expresses his thanks to Mr. H. C. Chapelow and a number of recorders for their careful daily readings of the meters, and to Mr. A. Voss for help in preparing the graphs.

Summary.

1. The use of moisture meters recording the "soil pull" or suction force at two depths in cultivated and grass orchards and fallow land during the year 1936 is described. The pull is nil at saturation and increases as the soil dries.

2. Both in grass orchard and cultivated orchard the soil at 36 in. gradually dried to a pull of over 60 cm. Hg (or approximately pF 2·9) in September, in spite of copious summer rainfall. The soil at 30 in. in a fallow plot showed practically no drying out. Plant roots and not evaporation are thus the controlling factor in water loss at this depth.

3. The soil at 12 in. did not reach 60 cm. pull in any case, in contrast with previous years. The maximum pull reached at 12 in. was 50 cm. in the grass orchard.

4. The grass appears to use up water at 12 in. much more than at 36 in.

5. The records support the statement that water falling on the soil surface wets it to a certain depth, depending on the amount of water, and that further movement to drier regions is very slow. Thus different parts of a soil block may remain at different states of dryness, corresponding to different soil pulls, for long periods.

6. Trees with roots extending into soil layers which exerted very different pulls continued to draw water from layers at the higher pull as well as those at the lower pull.

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SOIL MOISTURE STUDIES

II. MOISTURE VARIATION IN A PEAR ORCHARD

By W. S. ROGERS and D. N. SRIVASTAVA

Two porous-pot moisture meters were installed in a clean cultivated pear orchard in April and May, 1936. Their main purpose was to find out whether moisture deficiency in the soil has any bearing on the so-called " June Drop ", and to give some guidance as to the times when water injections into the tree might be beneficial. This was part of an intensive study of the problem of " Non-setting of Pear blossoms ", which will be reported later. As the moisture records themselves make an interesting comparison with paper I of this series, and also illustrate several new points, they are presented forthwith.

The meters, which were of the vacuum gauge type,* were installed near the two ends of the orchard, each one at a depth of 18 in. (i.e. with its pot extending 17 in. to 19 in. deep) at a distance of about 24 in. from the trunk of a 16-year-old Doyenne du Comice pear tree. Both trees were on Quince A rootstock. The soil was a medium loam similar to that described in Paper I (1). The depth of 18 in. was chosen because many of the roots are found at this depth and further it is approximately the middle of the soil block, which is about 36 in. deep. It has already been shown that moisture varies considerably at different depths, but for a single depth for comparison of two parts of the same orchard 18 in. appears very suitable.

Soil Moisture Records.

The variations in the soil pull, as shown by the meters, appear in Fig. 1. During April and until 10th May the soil pull at 18 in. was below 10 cm. Hg. From then until 30th June the soil dried steadily at this depth, in spite of fairly heavy rainfall, but the 1·5 in. rainfall on 28th and 29th June re-moistened the soil round meter B, reducing the pull to 5 cm. Meter A had risen rather farther, and needed an extra 0·5 in. rain in the next two days to bring its pull down to 12 cm. Both meters began rising again, and after a check in August, when meter B again fell more than A, they both continued to rise till mid-October. B reached 58 cm. a month later than A. Finally the soil round B was re-saturated to a pull of 5 cm. by the autumn rains on 2nd November, while that round A delayed a further five days. The contrast between the readings at the two ends of the plot on 3rd November, viz. A, 62·8, and B, 5·0 cm., was so remarkable that duplicate soil auger borings were taken near each meter, and dried, to check the meter readings. The surface soil, 0 to 3 in., was thoroughly saturated at the time, and contained 23·83 per cent. moisture (on dry weight). The soil at 18 in. round A contained only 11·30 per cent. moisture, while that round B contained 18·01 per cent. It was, therefore, borne out that at that time the soil had become re-moistened much deeper near meter B than near meter A.

* These meters were supplied by Messrs. A. Gallenkamp, Sun Street, London, E.C.2.

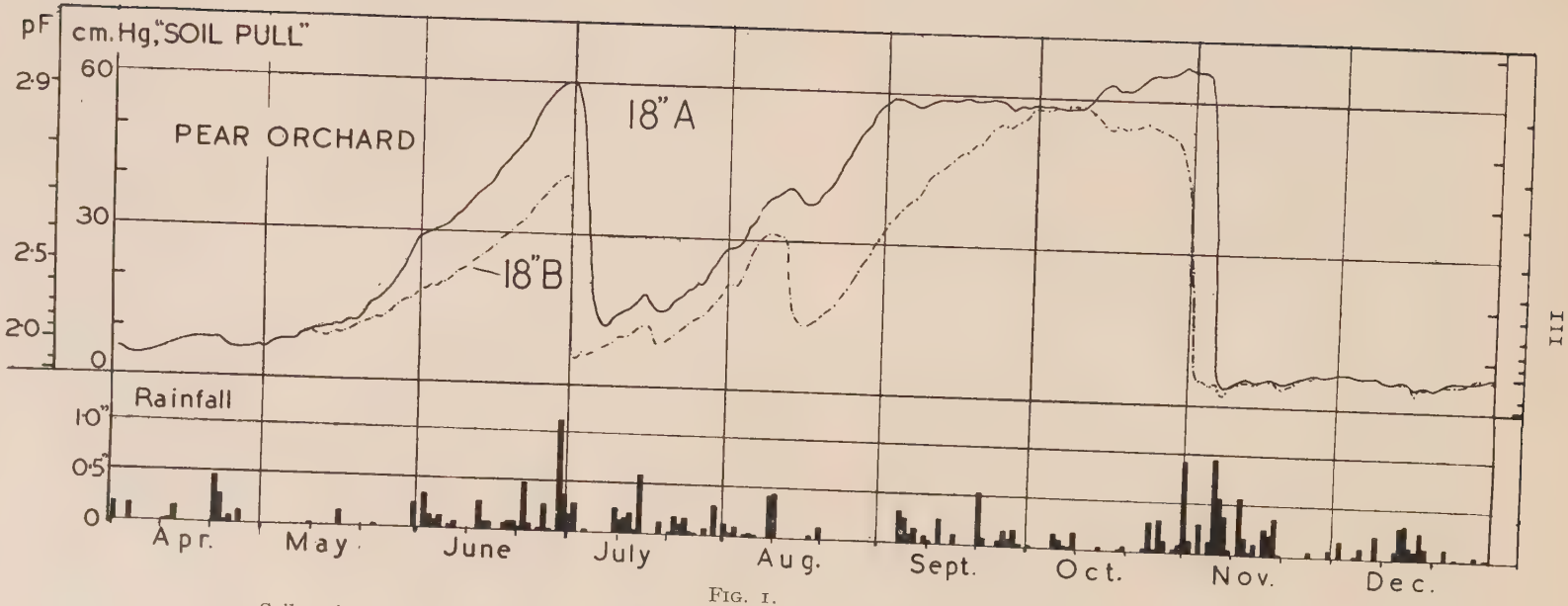

FIG. 1.

Soil moisture variation in a pear orchard, as shown by the "soil pull". O equals saturation.

Size of Tree and Water Usage.

Fig. 1 shows that the soil at 18 in. was at a lower pull at B than at A all through the summer, and only approached A for a few days in October. In the winter the pull is the same in both positions. The reason for the difference in pull in the summer became clear when the size of the two trees was considered. Although they were both Doyenne du Comice on Quince A, the tree at A happened to be considerably larger than that at B. Their relative sizes were : Tree A, height 5·0 m., mean spread 2·45 m., trunk girth, 40·6 cm., and Tree B, height 3·7 m., mean spread 2·25 m., girth 33·5 cm. This difference in size of tree is probably due to varying soil conditions other than soil moisture, and it can be seen in other trees at the two ends of the plantation.

Thus it is seen that the soil round a small tree dries more slowly and wets more quickly than that round an identical tree of larger size. This is a point which is obvious in an extreme case, but commonly escapes recognition when the contrast in size is small. In this case the smaller tree was about four-fifths of the size of the larger tree. It is a matter of some interest to note that in any case where trees are of different sizes, for whatever reason, as for example on different rootstocks, or fertilized in different ways, where they are planted at equal distances on similar soil profiles the larger trees will suffer from drought first. Under such conditions, therefore, in any drought period the soil moisture factor will tend to equalize their performance. This will apply particularly when the whole soil block has become permeated with roots. Such conditions appear to obtain in many Kent fruit tree plantations from about the sixth year onwards (2).

Moisture, Blossom Set and June Drop.

During the blossom period of Doyenne du Comice, which was from 24th April to 7th May in 1936, the soil pull at 18 in. was below 10 cm. Hg, i.e. the soil was saturated nearly to its " field capacity ". It is quite clear, therefore, that there was no moisture shortage during the blossom period of that year. From past soil moisture records in apple orchards here it would appear that it is unlikely that soil moisture would be deficient, at any rate in the deeper layers of soil, during pear blossom time under our conditions.

The " June drop " occurred mainly from 12th June to 28th June. During this time the soil at 18 in. dried from 30 cm. to 58 cm. pull beside meter A, and from 28 to 42 beside meter B. No considerable difference between the two trees in percentage of fruits that fell off was noted. It is clear that the period of " June drop " coincided with the beginning of drying out of the soil, though the conditions were by no means those of drought. At this time the leaves and fruits are all expanding rapidly together, so it is at least possible that a general " tightening up " of the moisture conditions in the tree may encourage the shedding of surplus fruits. More work is needed before a definite conclusion can be reached.

Summary.

1. Soil moisture variations during 1936, as shown by porous pot meters 18 in. deep beside 16-year-old pear trees, are discussed.

2. There was no moisture deficiency during the blossom period.

3. The June drop period coincided with the beginning of drying out of the soil. The soil conditions were by no means drought conditions, however.

4. The soil round a large tree dried more rapidly and became re-saturated more slowly than the soil round a tree four-fifths its size. Thus, wherever similar trees of

different sizes grow at equal distances on similar soil profiles, the soil moisture factor tends to equalize their performance under drought conditions, for the larger trees will suffer from drought first.

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WEATHER CONDITIONS DURING 1936

By H. C. CHAPELOW and H. M. TYDEMAN

It is unlikely that 1936 will be remembered for any outstanding occurrence of meteorological interest. Upon the balance, it will probably be considered that the year's weather was of a very average character and devoid of those events which have made certain years memorable. In its general features the year might be described as rather cold, dull and wet. Throughout the spring, almost until the end of May, temperatures were ranging below the average, April, in particular, being a very cold month, with snow, hail and sleet. It was during this month, with its severe and persistent north-east winds, that the blossoms of bush trees of sour cherries, although still in bud, were severely frosted, and the prospect of a crop ruined. Sweet cherry varieties were, fortunately, not affected in this locality. The fact that they escaped is thought to be due to their greater height above the ground, sweet cherries being usually grown as standards and sour cherries as bushes. The weather had improved considerably by the time the apples and pears were in bloom and they suffered no appreciable damage from frosts or cold. During the summer months, from June until the end of September, temperatures were about average, but conditions became cold again throughout the remainder of the year. The mean temperature of the air within the screen for the whole year at this Station was 48·4 degrees, rather more than a degree less than the twenty years' average. There were ninety-seven ground frosts altogether, certain of which were of considerable severity.

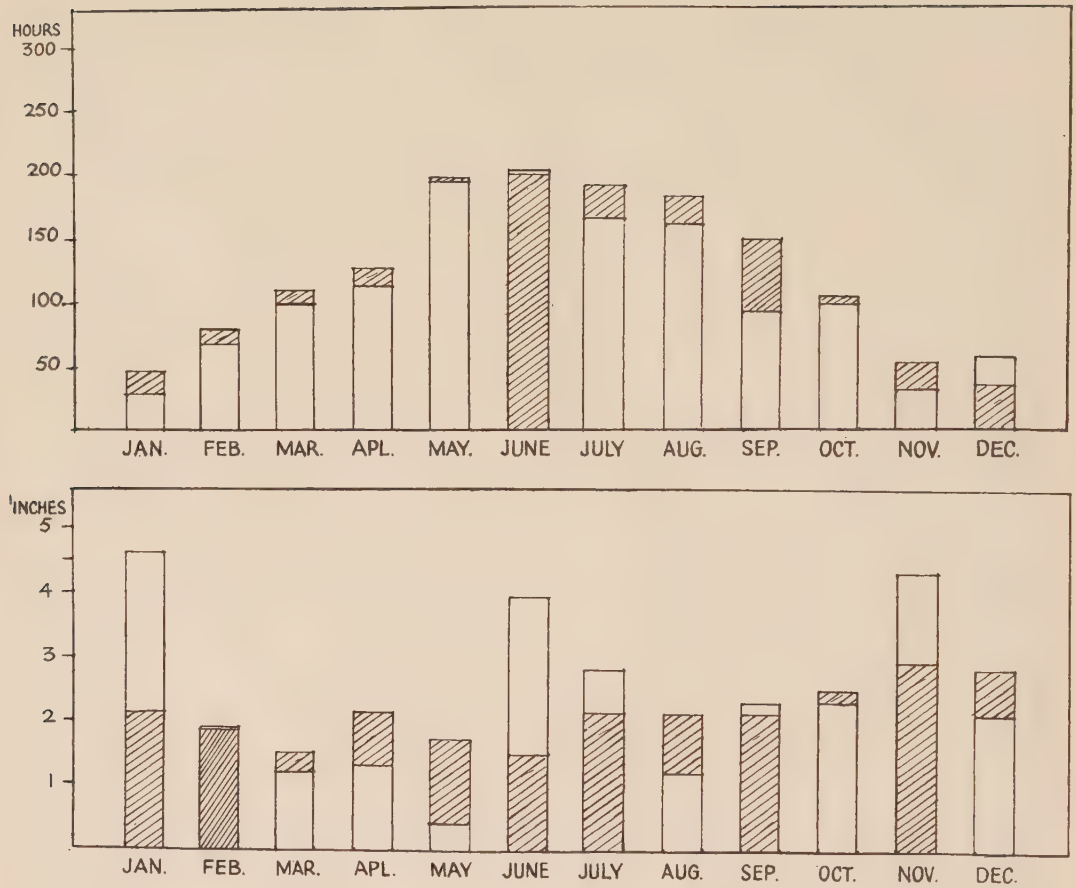
Sunshine was notably deficient, more particularly during July and September. Actually the total for the year, of 1,341 hours, was 142 hours in defect of the average for the previous twenty-one years. Rainfall, on the other hand, was in marked excess. The year's total of 28·59 inches was almost 3 inches greater than the average for the previous twenty-one years. January, June, July and November were the outstandingly wet months in this locality. A remarkable succession of thunderstorms during June, was in part responsible for the high rainfall total recorded during that month. Actually seven storms occurred in the last thirteen days of the month. Since these storms were usually of short duration, or occurred during the night, they did little to diminish the total of sunshine, and June was, in fact, the sunniest month of the year.

Upon the whole, extended periods of high wind were not experienced, although for a short period during mid-September winds of considerable velocity were recorded and caused some anxiety for the fruits hanging unpicked upon the trees.

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1936.

	Temperature in Screen.					No. of Ground Frosts.	Rainfall.			Sunshine.			Soil Temperatures.		
	Mean Maximum.	Mean Minimum.	Highest.	Lowest.	Mean.		Total in inches.	Heaviest fall in a day.	21 years' average.	Total hours.	Average per day.	21 years' average.	4 inches.	8 inches.	2 feet.
January ..	45·4	36·3	56	24	40·8	11	4·63	0·62	2·16	27·6	0·9	48·1	39·4	39·9	40·8
February ..	42·0	31·6	54	17	35·9	21	1·87	0·55	1·84	81·0	2·8	68·1	35·6	36·8	39·0
March ..	51·3	34·4	61	26	42·8	12	1·21	0·21	1·50	98·9	3·2	119·2	41·4	41·6	42·1
April ..	50·4	37·3	62	27	43·8	14	1·31	0·46	2·18	113·4	3·8	127·8	45·5	45·3	46·2
May ..	62·9	44·6	77	36	53·7	2	0·44	0·25	1·74	194·3	6·3	196·1	54·9	49·5	53·6
June ..	69·4	50·4	85	36	59·9	0	3·95	1·11	1·46	202·5	6·8	202·0	59·8	59·1	58·9
July ..	67·0	53·0	76	42	60·0	0	2·80	0·59	2·18	166·3	5·6	195·3	62·0	61·3	61·9
August ..	70·5	51·5	81	42	61·0	0	1·20	0·44	2·18	161·4	5·2	184·0	62·0	61·4	62·0
September ..	63·7	49·1	76	35	56·4	1	2·34	0·54	2·13	93·5	3·1	151·1	58·9	58·8	60·9
October ..	56·0	39·7	67	27	47·8	12	2·38	0·92	2·51	107·6	3·5	100·0	48·0	48·9	52·0
November ..	48·4	36·5	55	27	42·4	12	4·32	0·57	2·97	35·1	1·2	54·3	42·9	44·0	46·7
December ..	47·0	35·3	66	22	36·2	12	2·12	0·34	2·81	59·7	2·0	37·4	40·2	40·9	42·8

TOTAL SUNSHINE IN HOURS.



Diagrams showing Total Sunshine and Rainfall during 1936 as compared with 21 years' average. Shaded portion 21 years' average.

HOPS

CULTURAL TRIALS WITH HOPS. II*

THE EFFECT OF DISTANCE OF PLANTING AND NUMBER OF BINES: A FINAL REPORT ON THE TRIAL WITH THE SEEDLING L21

By F. H. BEARD

Introduction.

From 1897 until 1902 several field experiments with hops were carried out at Wye and other centres by Sir Daniel Hall and others (3). One of these trials was designed to compare several planting distances in the Butcher system of training with both the Umbrella and Worcester systems. Each treatment consisted of a single plot of about half an acre in extent. The results obtained from this experiment favoured the Umbrella system and the closer planted plots of the Butcher system. In the area devoted to the Butcher system, there were, however, variations in the width of the alleys, and a consequent alteration in the slope of the strings, which may possibly have influenced the cropping to some extent. The Umbrella system plot was planted at 6 ft. square. This was also the closest distance tested in the Butcher system plots. The greatest differences in yield were obtained in a year of short general crop.

When the Hop Research programme at East Malling was extended to include cultural trials it was thought well worth while to elaborate, under modern conditions of field trial technique, some of the earlier indications obtained at Wye. It would be impossible to test the various training systems within a reasonable limit of space, as they do not readily adapt themselves to small scale plots of which at least four replicates would now be considered necessary to ensure significant results.

It was, however, considered desirable that trials to test the effect of distance of planting, number of bines per string, time and severity of cutting and severity of pulling, should be initiated as soon as ground and material became available.

For this work it was originally intended to use both commercial varieties and the best of Prof. Salmon's New Seedlings, but the discovery that nearly all the latter growing in the East Malling gardens were carriers of the "Mosaic" disease, meant that only the new varieties and the Fuggles hop could be utilized. However, since the new varieties comprise a great range of vigour and bearing habit, they are admirably suited for such investigations. At one and the same time it was thus made possible to try and elucidate certain general principles underlying cultural practices and also to obtain information regarding the most suitable methods of growing Prof. Salmon's new varieties.

Results obtained from a series of manurial experiments with hops at East Malling had shown that when certain hills in a plot had been killed by disease, the yield per hill of the adjacent hills was increased (1).

In view of these results and those obtained in the early Wye experiments, which have already been referred to, it was decided to investigate further the effect of distance of planting.

* A preliminary account appeared in E.M.R.S. Ann. Rep., 1933 (May, 1934), 132-6.

Plan of Experiment.

A trial was laid down in the spring of 1928 to test three different spacings combined with the training of different numbers of bines up each string.

The variety selected for the experiment was the seedling L21 (Tolhurst × English male) which possesses only moderate vigour, making practically no "heads" over the top wire, but it produces short fruiting laterals along the whole length of the bine from the breast wire upwards, and yields good crops for an early variety. At the time, L21 was considered to be a promising early hop, but has since proved to be unacceptable to brewers. Incidentally, it is very resistant to Downy Mildew (*Pseudoperonospora Humuli*) but is an immune carrier of the "Mosaic" disease.

The Butcher system of training was employed, with alleys 7 ft. wide, the top and breast wire being 13 ft. 6 in. and 4 ft. 6 in. respectively from the ground. Three strings were placed to each hill, which was cut (dressed) in the normal manner in March. Little pulling was necessary, only the rankest bine being removed before training commenced. The trial was divided into four blocks and one 90 ft. row of each treatment occurred at random in each block. Guard hills were situated at the beginning and end of each experimental row.

There were in all nine different treatments to test all combinations of three distances of planting and three degrees of training. These are set out below and lettered from A to K for convenience in future reference :

A. Hills 9 ft. apart, 1 bine per string.
B. Hills 6 ft. apart, 1 bine per string.
C. Hills 3 ft. apart, 1 bine per string.
D. Hills 9 ft. apart, 2 bines per string.
E. Hills 6 ft. apart, 2 bines per string.
F. Hills 3 ft. apart, 2 bines per string.
G. Hills 9 ft. apart, 3 bines per string.
H. Hills 6 ft. apart, 3 bines per string.
K. Hills 3 ft. apart, 3 bines per string.

Records were taken on both the quantity and quality of the crop.

Cropping.

The first measurable crop in 1930 was light and insufficient to be dried separately. It was, therefore, weighed green for each individual plot and gave significant differences due to distance of planting only. In 1931 and subsequent years the crop was sufficiently heavy to permit the drying of the crop from each plot separately. The weight of dried hops provided a more accurate measure of the crop as it is not affected by climatic conditions at the time of picking, and variation in the weight of individual pokes. The weighing of the green hops was, therefore, discontinued in 1933.

Table I gives the average yield per acre, calculated from the weight of dried hops, for each treatment for the six seasons 1931-6. It will be noticed that although heavy and light crops occur in alternate years, the relative position of the plots remains unchanged.

In each season Series A (9 ft. 1 bine) has given the lightest crop with an average of only 13·76 cwt. per acre, whilst Series K (3 ft. 3 bines) has yielded the heaviest crop, with an average of 24·93 cwt. per acre.

The plots with the hills at 3 ft. apart (Series C, F and K) all gave heavy crops. Where the hills were 6 ft. apart (Series B, E and H) the cropping was quite good in all

TABLE I.

AVERAGE YIELDS, 1931-36.

Series.	Treatment.	1931, cwt. per acre.	1932, cwt. per acre.	1933, cwt. per acre.	1934, cwt. per acre.	1935, cwt. per acre.	1936, cwt. per acre.	Mean 1931-1936, cwt. per acre.
A.	9 ft. 1 bine	12·19	16·36	12·04	16·04	12·80	13·11	13·76
B.	6 ft. 1 bine	18·67	20·53	16·98	21·76	17·10	20·06	19·18
C.	3 ft. 1 bine	23·15	26·24	21·14	25·00	20·52	24·23	23·38
D.	9 ft. 2 bines	15·90	19·14	16·67	19·74	15·88	21·29	18·10
E.	6 ft. 2 bines	19·45	24·08	19·91	22·07	18·36	21·61	20·91
F.	3 ft. 2 bines	23·77	27·16	21·45	24·84	21·14	25·77	24·02
G.	9 ft. 3 bines	14·51	18·52	16·67	20·67	17·43	19·89	17·95
H.	6 ft. 3 bines	22·22	25·47	19·45	23·76	20·37	26·08	22·89
K.	3 ft. 3 bines	24·39	29·63	21·45	25·77	22·69	25·62	24·93
	Gen. Mean	19·36	23·01	18·42	22·18	18·44	21·96	20·57
	S. E.	1·168	1·027	1·137	0·972	0·972	1·594	
	Sig. Diff.	3·410	2·998	3·315	2·834	2·834	3·665	

cases. The plots with hills at 9 ft. apart (Series A, D, G) gave poor yields, where one bine was trained up each string (Series A), and only moderate crops where there were two and three bines per string.

The heaviest crops were obtained in 1932, a season which proved very favourable to the closely planted hills. This is in contrast to the results of the Wye experiments when close planting came out best in years of light general crop. It should, however, be remembered that the Wye trials were carried out with commercial varieties which may produce excessive bine in seasons of heavy cropping, when the closely planted hills will naturally suffer most from overcrowding. The variety L21 has never made excessive bine growth under East Malling conditions.

EFFECT OF DISTANCE ON CROPPING.

Throughout the period of the trial the differences in yield due to the distance apart of the hills have shown very clearly. The differences in cropping were greatest in 1931 and 1932; they were reduced in 1933, from which year they have remained almost stationary.

It will be seen on looking at Table II that closer planting consistently gave the heavier crops. Where the hills are 9 ft. apart in the rows the average yield for the six

TABLE II.

DISTANCE ONLY.

Distance.	1931, cwt. per acre.	1932, cwt. per acre.	1933, cwt. per acre.	1934, cwt. per acre.	1935, cwt. per acre.	1936, cwt. per acre.	Mean 1931-1936, cwt. per acre.
9 ft.	14·20	18·01	15·13	18·82	15·28	18·11	16·59
6 ft.	20·13	23·35	18·78	22·51	18·63	22·58	21·00
3 ft.	23·76	27·68	21·35	25·18	21·45	25·21	24·11
Gen. Mean	19·36	23·01	18·42	22·18	18·44	21·96	20·57
S. E.	0·6729	0·5931	0·6562	0·5612	0·5612	0·6112	
Sig. Diff.	1·969	1·731	1·916	1·648	1·648	1·793	

years was only 16·59 cwt. per acre, whilst the hills at 6 ft. and 3 ft. apart have averaged 21·00 cwt. and 24·11 cwt. per acre respectively. Although the yield per acre was greatly increased by closer planting, *the yield per hill* was considerably increased by wider spacing. The average annual weight of dried hops per hill at 9 ft. apart was 2·63 lb. compared with 2·27 lb. and 1·30 lb. at 6 ft. and 3 ft. apart.

Effect of Number of Bines on Cropping.

The number of bines trained up each string influenced the cropping to a much smaller extent than did distance of planting. It was difficult to obtain three bines of equal vigour per string with the variety L21, and the third bine was sometimes more backward than the other two bines. Should the tip of a bine be damaged during training, the checked bine usually grows away again vigorously where there is only one bine per string, but where there are three bines per string, the unchecked bines tend to obtain the lead and the damaged bine is often crowded out. This checking effect is also present, but to a lesser extent, where two bines are trained up each string.

In 1932, 1933 and 1936 the difference between 1 and 2 bines was significant, but not that between 2 and 3 bines.

In 1931 and 1934 there were significant differences between 1 and 3 bines only. In 1935 the differences between 1 and 3 and between 2 and 3 bines were significant, but the differences between 1 and 2 bines were not significant.

In no season have there been significant differences between all numbers of bines.

Table III.

Number of Bines Only.

No. of bines.	1931, cwt. per acre.	1932, cwt. per acre.	1933, cwt. per acre.	1934, cwt. per acre.	1935, cwt. per acre.	1936, cwt. per acre.	Mean 1931-1936, cwt. per acre.
1	18·93	21·04	16·72	20·94	16·82	19·14	18·78
2	19·69	23·46	19·34	22·21	18·37	22·89	20·99
3	20·37	24·54	19·19	23·42	20·16	23·86	21·92
Gen. Mean	19·36	23·01	18·42	22·18	18·44	21·96	20·57
S. E.	0·6729	0·5931	0·6562	0·5612	0·5612	0·6112	
Sig. Diff.	1·969	1·731	1·916	1·648	1·648	1·793	

It will be seen from Table III which gives the yields for each bine treatment over the six seasons, that even where the differences are significant between 1 and 2 bines, and between 2 and 3 bines they are only just significant. It is, therefore, not surprising that as mentioned above, one or the other difference was obscured each year. However, 3 bines per string always gave a definite increase in crop over 1 bine.

It will be noticed that in 1933 the yields from the plots with 2 and 3 bines per string were almost identical. In this season the hop garden suffered severely from a hailstorm in June, and as previously mentioned the third bine has more difficulty in getting away after a check.

The *yield per hill* is not greatly influenced by the number of bines per string, the average annual yield of dried hops per hill was 1·86 lb., 2·10 lb., 2·24 lb. respectively for 1, 2 and 3 bines per string.

Effect of Number of Bines at Each Distance.

Where the hills were planted at 9 ft. apart, significant differences in cropping between 1 and 2 or 3 occurred in five years out of six, but there was no significant difference between 2 and 3 bines per string. At 6 ft. apart, the difference between 1 and 2 bines and between 2 and 3 bines was only once significant, between 1 and 2 bines in 1932 and between 2 and 3 bines in 1936. There was a significant difference between 1 and 3 bines in four years out of six.

Although with the hills at 3 ft. apart the average yield was increased slightly with the number of bines, the figures were only significant in 1932, when there was a difference between 1 and 3 bines.

It was suggested by a leading hop-grower that the number of bines per acre greatly influences the size of the crop. This theory has not been confirmed by the results of this trial. Treatments C (3 ft. 1 bine), E (6 ft. 2 bines), and G (9 ft. 3 bines), all have 90 bines per plot, but their average yield has been 23·38, 20·91 and 17·95 cwt. per acre respectively. Also Series H (6 ft. 3 bines) with 135 bines per plot, and Series K (3 ft. 3 bines) with 270 bines per plot, have cropped at an average rate of 22·89 and 24·93 cwt. per acre respectively over the six years, and are not significantly different in cropping from Series C (3 ft. 1 bine) with only 90 bines per plot and an average yield of 23·38 cwt. per acre.

Quality of the Crop.

It was always apparent that the cones on the plots in Series A (9 ft. 1 bine) were riper and better developed at picking time. In order to obtain a measure of any variation in the size of the cones due to the treatments, samples of cones were graded in two seasons of very different climatic conditions.

In 1931 which was wet and cool in July and August, differences in the size of the cones between certain treatments were very noticeable on inspection of the plots. Two random samples of the green hops were collected from the pickers' bins in two plots in each treatment. From these samples 500 cones were graded in four classes (under 2 cm. long, 2 to 2·5 cm., to 3 cm., and over 3 cm.).

Table IV gives the percentage of cones over 2·5 cm. long for each treatment in 1931 and 1932. It will be noticed that in 1931 the 9 ft. and 6 ft. plots with 1 bine per string had the best developed cones, whilst the plots with 3 ft. 1 bine, 3 ft. 2 bines, and 6 ft. 3 bines, had very poorly developed cones. Cone development was only moderate on the following plots: 3 ft. 1 bine, 9 ft. 2 bines, 9 ft. 3 bines, and 6 ft. 2 bines.

Table IV.

Size of Cones—Percentage over 2·5 cm. in Length.

	1931.			1932.		
	9 ft.	6 ft.	3 ft.	9 ft.	6 ft.	3 ft.
1 bine	32·1	34·9	22·4	67·07	68·17	58·05
2 bines	24·6	19·1	10·6	63·32	64·87	50·65
3 bines	24·7	13·9	10·1	62·52	58·72	53·73
	General Mean 21·38			General Mean 60·79		
	S. E. 4·6			S. E. 2·2186		
	Sig. Diff. 13·4			Sig. Diff. 6·31		

In 1932, which was a season favourable to good cone development, all plots appeared equal on inspection of the rows. Samples of cones were, however, again graded, but the technique adopted was slightly modified after the examination of the previous year's data. Two samples of cones were taken from three plots instead of two, and only 250 cones were graded from each sample. This gave a lower experimental error, indicating differences of about 6 per cent. compared with 13 per cent. in the previous year. As was expected, all treatments had a high percentage of well-developed cones. The improvement in cone development was most marked in those plots which had the most poorly developed cones in 1931. The 3 ft. 3 bine plots which had only 10 per cent. of the cones over 2·5 cm. long in 1931 had more than 53 per cent. of the cones over 2·5 cm. long in 1932, whilst the percentage of cones over 2·5 cm. long on the 9 ft. 1 bine plots had increased from 32·1 per cent. to 67·07 per cent.

Notwithstanding the very great increase in the size of the cones, the relative positions of the treatments remained almost unchanged. In Table V the effect of Distance and Number of Bines on cone size is shown separately.

TABLE V.

DISTANCE AND NUMBER OF BINES: SIZE OF CONES—PERCENTAGE OVER 2·5 CM. LONG.

Distance.	1931.	1932.	No. of Bines.	1931.	1932.
9 ft.	27·1	64·30	1	29·8	64·43
6 ft.	22·6	63·92	2	18·1	59·61
3 ft.	14·4	54·14	3	16·2	58·32
Gen. Mean	21·38	60·79		21·38	60·79
S. E.	2·65	1·281		2·65	1·281
Sig. Diff.	7·7	3·64		7·7	3·64

The differences between 3 ft. and 6 ft. apart were significant in each year, but there was no significant difference between 6 ft. and 9 ft. apart. In 1931 the percentage of well-developed cones on the 9 ft. plots was almost double that on the 3 ft. plots.

Where only one bine was trained up each string the cones were definitely larger, but there was practically no difference in this respect between 2 and 3 bines.

In view of the above results it was not considered necessary to grade samples of cones in subsequent seasons. The cones were well developed in all other years except 1935, when drought during July was probably responsible for rather small cones on all plots.

Although the summer of 1936 was rather wet, the cones on all plots were well developed in contrast to 1931, the possible explanation being that in 1936 August was dry and warm, whilst in the other year it was wet. It was considered likely that on the plots with the better developed cones the hops would "weigh" better and that fewer bushels of green hops would be required to yield a hundredweight of dried hops; there was, however, no difference in this respect due to the treatments, although there was considerable seasonal variation in the "weight". The fact that the smaller hops go down closer in the measuring basket evidently compensated for the heavier individual weight of the larger cones. The hops weighed the heaviest in the seasons 1932 and 1935, whilst in 1931 they were very light.

In 1931 the dried hops from each treatment were pressed separately, and Mr. C. G. Tosswill of Messrs. Wigan, Richardson & Co. kindly examined samples cut from

the pockets. The hops from the plots with the better developed cones were considered to have the higher market value. Samples of the dried hops from the two extreme treatments (A, 9 ft. 1 bine, and K, 3 ft. 3 bines), were analysed for preservative value, in the seasons 1931-4 inclusive. In each year the hops from Series A (9 ft. 1 bine) were slightly richer, the differences were, however, only small, the average difference being only 0·44 per cent. for the four seasons.

Discussion of Results.

As records of the cropping have been obtained over six seasons of very different climatic conditions, it seems fairly safe to assume that the results obtained are likely to be repeated with only minor seasonal variations. The data obtained during the last three seasons have confirmed the findings based on the first three years' results (2).

In every season the hills at 3 ft. apart in the rows gave the highest yields, though in one season (1931) this was associated with poorly developed cones where more than one bine was trained up each string.

The plots having the hills 3 ft. apart and 1 bine per string gave high yields combined with well-developed cones even in an unfavourable season. In comparing this treatment with the wider spaced plots the disadvantages of the extra cost of several cultural operations must be borne in mind. The relative cost and returns for the three distances of planting are discussed in the appendix.

The common commercial plant 7 ft. × 6 ft. with two bines per string gave quite good crops, with an average of nearly 21 cwt. per acre.

Although the yield per hill was markedly increased by wide spacing, a weak growing variety like L21 has not benefited to the full from the wide planting. It appears likely that certain very vigorous varieties such as many of the New Mexican hybrids, may be able to benefit from spacing wider than normal, and this is now being tested in a new experiment.

The trial has shown that the number of bines per string is of much less importance than the distance between the hills. The average crop for the 6 ft. 1 bine plots has been only 3·71 cwt. per acre less than that of the 6 ft. 3 bine plots. Where the hills were 3 ft. apart in the rows the differences due to the number of bines per string were too small to be significant. In the case of the plots with the hills at 9 ft. apart, two bines per string has given a considerable increase of crop over one bine.

This slight effect of the number of bines per string is of particular interest, since in certain seasons a fairly large number of bines in commercial gardens may be affected with the terminal spike form of Downy Mildew. The results of this trial indicate that so long as at least one good bine remains to each string, there is little risk of any considerable reduction in the yield per acre.

In conclusion it may be inferred that weak growing varieties can be planted more closely than normal, with a consequent increase in the crop. Close planting will probably be most advantageous under conditions where bine growth is usually slight. Where close planting is employed it appears desirable to reduce the number of bines trained up each string in order to secure better developed cones.

Appendix.

Relative Cost of the Treatments.

The cost of several cultural operations, such as cutting, training, stringing, etc., are largely influenced by the number of hills per acre. In Table VI an attempt is made to estimate the relative cost of these operations for the different distances. The figures

TABLE VI.

RELATIVE COSTS AND RETURNS FOR EACH TREATMENT (Per Acre).

Series.	Treatment.	Cost of Cultural Operations.	Average Crop.	Value of Crop.	Increase or Decrease in Cost over Series B. E. H.	Increase or Decrease in Value of Crop over Series E.
		£ s. d.	cwt.	£	£ s. d.	£
A.	9 ft. 1 bine	7 0 0	13·76	124	− 3 5 0	−64
D.	9 ft. 2 bines	7 0 0	18·10	163	− 3 5 0	−25
G.	9 ft. 3 bines	7 0 0	17·95	162	− 3 5 0	−26
B.	6 ft. 1 bine	10 5 0	19·18	173	—	−15
E.	6 ft. 2 bines	10 5 0	20·91	188	—	—
H.	6 ft. 3 bines	10 5 0	22·89	206	—	+18
C.	3 ft. 1 bine	21 0 0	23·38	210	+10 15 0	+22
F.	3 ft. 2 bines	21 0 0	24·02	216	+10 15 0	+28
K.	3 ft. 3 bines	21 0 0	24·93	224	+10 15 0	+36

Yields in brackets do not differ significantly.

are not intended to be accurate costings, but merely to serve as an indication of the relative cultural expenses and value of the crop for each treatment. No allowance has been made for any effect that the number of bines per string may have had on the costs, but it is likely that where only one bine is trained up, the training expenses would be rather less than where there are two or three bines per string.

The value of the crop has been taken as £9 per cwt., but it should be remembered that in one season (1931) when the general cone development was poor, the hops from certain plots with larger cones were of greater market value. The gross return for each treatment is based upon the average crop over the six year period. After allowing for the additional expenditure involved, close planting at 3 ft. has given increased returns over that of 6 ft. 2 bines, whilst wide planting at 9 ft. has greatly reduced the returns, particularly where only one bine is trained up each string.

Although the differences in cropping due to number of bines at 3 ft. have not been statistically significant except in one year, three bines have always given slightly heavier yields, and for the purpose of the relative returns it is fairly safe to assume that there will be a slight financial gain with three bines as compared with either one or two bines. It must, however, be remembered that in one year when the cones were poorly developed, the crop from the plots at 3 ft. with 2 and 3 bines per string, was of lower value than where only one bine was trained up each string.

ACKNOWLEDGMENTS.

The writer is indebted to Mr. T. N. Hoblyn for assistance in planning the trial and for the statistical analysis of the records in 1930 and 1931, and also to Miss J. L. Edgar who has analysed the figures in subsequent years. Thanks are also due to Mr. J. Amos for suggestions and assistance in the preparation of the appendix, and on many other occasions. The cones were graded by Messrs. H. M. Tydeman and J. B. Collard in 1931 and by Messrs. E. G. Ing and A. C. Fabergé in 1932.

SUMMARY.

The data obtained over a period of six years show that :

1. The yield per acre was greatly increased by close planting.

2. The yield per hill was increased by wide spacing.

3. The number of bines trained up each string had considerably less effect on the cropping than distance of planting.

4. In one season the size of the cones and consequent quality of the crop was adversely affected by certain combinations of distance and number of bines per string.

5. The results are discussed with a view to applying the findings to commercial practice. The cost of several cultural operations are influenced by the distance of planting and this aspect is dealt with in an appendix.

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HORTICULTURAL METEOROLOGY*

A NOTE ON FROST DAMAGE INVESTIGATIONS

By C. E. CORNFORD

As a result of the great losses experienced in the fruit growing industry from the severe frost of 16-17th May, 1935, a Conference on Frost Damage was held at this Station on 11th September of that year, and, in response to a resolution from that Conference, the Ministry of Agriculture gave a provisional grant in January, 1936, to enable the Station to carry out preliminary climatological investigations in collaboration with a special sub-committee representing various aspects of the problem.

For reasons given below it was decided that it was essential to begin these investigations by studying air currents and cold air flows in relation to frost damage to fruit trees, especially during their blossoming period. This particular problem has never been tackled before, and it was found necessary to begin from the very beginning in an attempt to find suitable instruments and to devise methods of using them for the purpose of collecting, principally, records of the speed and direction of air movements and of air temperature.

Air Movements.

The problem of recording the speed and direction of low velocity winds has been studied in collaboration with the Meteorological Office and Professor D. Brunt. Thistledown, hanging threads, smoke and certain instruments have been experimented with. Among the latter is an instrument which has been devised for giving a continuous record, on a sheet of paper wrapped round a revolving drum driven by a clock, of the speed and direction of the very light air drifts that occur on a frosty night. The instrument also records the temperature of the air.

Katabatic or Downhill Winds.

These winds are of importance to the fruit-grower for the following reasons.

(1) In undulating topography, not near the sea, katabatic winds may result in the formation of frost-pockets where an exceptionally heavy toll might be taken of buds, blossoms and young fruits in the spring.

(2) The speed of these winds on slopes may be such as to interfere seriously with orchard heating operations.

Consequently, it was thought that if the nature of these winds, i.e. their origin, speed, direction, depth, temperature, etc., was better understood the most reliable method of frost prevention for each orchard might be determined.

Katabatic winds are produced on clear calm nights, in all seasons of the year (4). On such nights the heat in the soil and trees, and in every object exposed to the sky, is radiated into space and the objects cool in consequence. The air in contact with these objects also cools and becomes denser than the air a few feet, or yards, above it. The

* See also "Weather Conditions during 1936" on p. 114 of this Report.

heavier or denser air then moves into the lowest position available. If this cold and relatively heavy air is produced on a slope it may flow down the slope, thus constituting a downhill, or katabatic, wind.

The truth of these broad facts has been confirmed by observations made at night with the help of some of the apparatus mentioned above. More detailed knowledge of katabatic winds has, however, come to light. It has been found that so far on all so-called calm evenings there is a light and relatively warm wind blowing on the hill tops between 300 and 600 feet high, and perhaps at lower altitudes on most occasions. This wind does not usually change its direction. It may be regarded as the " remains " of the wind that blew on the preceding day, and it is convenient to name it the upper wind.

Where the downhill wind blows in the same direction as the upper wind, the presence of the downhill wind is not easy to detect. Where, however, the downhill wind and the upper wind blow in opposite directions the downhill wind may be fairly easily detected.

Suppose the upper wind is blowing from the south on a night favourable for the formation of downhill winds, and we walk from the top to the bottom of a fairly steep south-facing slope whose top is 600 feet high. At the top a light wind, the upper wind, is blowing from the south. As we get lower the upper wind, which is blowing *uphill* diminishes in speed until a place is reached where the air is still, or nearly so. This area of still air might be about 20 feet wide. Below this area the air moves *downhill*. This is the beginning of the downhill wind. If the downhill wind is followed it may be found that it keeps to the lowest level until either it reaches the bottom of the hill, where a lake of cold air forms, or it becomes exposed to the upper wind and is destroyed by it.

As the level of this lake of cold air rises it may reach a height at which the blossom buds become surrounded by it causing their temperature to fall well below freezing point, when damage may result.

If a wood lies in the path of the downhill wind, the latter has been found to pass through it with little diminution in speed. A downhill wind was found on a slope that is entirely covered in a rather open wood. In this case the downhill wind flowed through the leafy brush-wood and among the trunks.

In general it can be said that on a slope facing the upper wind, the downhill wind is able to counter-balance the upper wind and to overpower it in proportion as the downhill wind is protected from the upper wind by rows of trees, hedges, gullies and banks, and in proportion to the steepness of the slope. Thus, at a lower level where the slope is not so steep, the upper wind may be able to overpower the downhill wind, and to destroy it by blowing it uphill again.

Suppose the upper wind does not blow directly upon the south-facing slope, but that it blows from the south-west. Then the downhill wind tends to travel to the south-east. This behaviour of the downhill wind is not in accordance with the notion that the " cold air flows downhill like water ", as is so often stated.

In the cold-air lake the low temperature of the air is partly due to its contact with the ground forming the bed of this lake, and is thus not entirely the result of streams of cold air flowing down from the higher land.

With regard to the air temperatures associated with downhill winds, one can say that generally they help to produce colder air in the valley bottoms than on the hill tops and hill sides. But this is by no means always the case, and it may be slightly warmer in the valley bottom on some frosty nights than it is at higher altitudes on the sides of that valley.

A common speed for downhill winds is one mile per hour, and a common temperature-difference between a valley bottom and a hill top 300 feet higher is 8° F., but both these figures would be greatly increased in a very sharp frost.

Can a fruit-grower do anything to control these downhill winds which help to cause frost damage? He cannot easily change the direction of the upper wind, or the topography of his farm, but he may be able to alter, to some extent, the size and orientation of the woods and tree-belts that often protect the downhill wind from the upper wind.

All observations made so far tend to support the view that the upper wind is the greatest natural destroyer of the downhill wind, and that consequently where frost damage occurs on relatively high ground that damage might be decreased by exposing the trees as much as possible to the upper wind.

It will be noticed that the above statements are generalized and more detailed research is necessary before specific recommendations can be made. For example, it is not yet known how dense or wide a belt of trees must be in order to act as a protection to the downhill wind.

Temperatures.

With regard to the problem of taking air temperatures in the field on frosty nights, which was studied with the help of the Meteorological Office, it was evident from the first that accurate data could not be obtained by merely hanging thermometers with bare bulbs on the trees. Such thermometers do not record air temperatures on a frosty night; they usually record a temperature well below the air temperature. The number of degrees below the air temperature which the bare-bulb thermometer records is not constant but depends on the rate at which the bulb is losing heat compared with its rate of gaining heat. The bulb loses heat chiefly by radiation to the night sky, and it gains heat chiefly by contact with the air. On a frosty night the rate of loss of heat from a bare bulb is usually greater than that of the gain in heat and in consequence the thermometer records a temperature below that of the air temperature.

The loss of heat from the bulb by radiation can be prevented by arranging a screen around it, which is usually made of either metal or wood. If the screen is made in such a way that air can circulate freely through it while the bulb is prevented from "seeing" the night sky (and the earth), and if the thermometer is more than about 3 feet from the soil, it will record air temperatures with fair accuracy. The Meteorological Office in this country uses a white-painted screen of wood with louvered sides called a Stevenson screen. Owing to its lack of portability this screen could not be used for experimental work in orchards where frequent readings of air temperature at many places both near the soil and up to 20 feet above it were required. A small metal screen was therefore used, cylindrical in shape, about 2 inches long, and 1 inch in diameter. It was fitted to the thermometer stem by means of a cork. The ventilation in these screens was found to be not sufficient for giving accurate results under the conditions of almost "still" air that often exist at certain places on frosty nights. In order to achieve the required degree of accuracy it was found necessary to fit a screen over the bulb and to ventilate the screen with a forced draught.

A bare bulb thermometer may, however, be used to record air temperatures accurately without the aid of an artificially ventilated screen. A thermometer with a bare bulb records air temperatures accurately after being whirled on the end of a short piece of string for two minutes.

On a frosty night there are relatively large variations in temperature in the first one or two feet above the soil where the coldest temperatures are found, and in this

region rapid fluctuations occur. Hence when taking air temperatures at night the thermometer should be kept at least 3 or 4 feet high. Little reliance can be placed on air temperatures obtained below this level by ordinary methods. How then can the air temperature near strawberries be taken? It is necessary to use sensitive recording thermometers of special design (1). The whole problem of the prevention of frost damage to strawberries appears to be a special one.

The question regarding the air temperature near strawberries raises a question touching a more fundamental problem, namely, does the horticulturist really require a knowledge of air temperature? Is it not of more importance to know the temperature of the bud itself, or that of the flower, young fruit, or other part liable to frost damage? Recent research work carried out at Leeds in this country has shown that fruit buds are not necessarily at the same temperature as the air surrounding them (3). Hence, it seems likely that greater attention may have to be paid to bud temperature in the near future.

In the experiments carried out in 1936 the temperature of the air was singled out for measurement for the following reasons.

(1) It can be fairly easily measured with accuracy.

(2) Investigators in the past have used the air temperature.

(3) The temperatures at which buds, flowers and young fruits are destroyed are, in American literature, given in terms of air temperature.

(4) Orchard heaters are used to heat the air, which in turn heats the buds, flowers and young fruits with which it comes into contact.

(5) The low temperatures that destroy buds, flowers and young fruits of English varieties are not yet known with accuracy, and fruit-growers have therefore to use American figures (2) to guide them when using orchard heaters. These are usually given to the nearest degree Fahrenheit. Hence, those who use these figures must have thermometers which are sufficiently accurate, properly sited and screened, so that the air temperature is known to the nearest degree. Otherwise, assuming the killing temperatures are correct, loss may be incurred by lighting up either too early when more fuel is consumed than is necessary, or too late, resulting in a reduced or lost crop.

(6) Even if those in this country who use orchard heaters do not avail themselves of the American figures for the temperatures at which buds, flowers, and young fruits are destroyed, reliable records of air temperatures taken in the orchard will, in course of time, provide valuable information on the lethal temperatures at various stages of development of the flowers, and young fruit.

The air temperature on frosty nights was found to fluctuate, so that to measure differences of air temperature between a point in the heated area and another point a few hundred yards from the heated area it is necessary, in order to make a fair comparison, for an observer to stand at each point and for each observer to record temperatures simultaneously. The thermometers should be held at the same height above the ground, and on the same contour.

No conclusion could be drawn as to the effectiveness of orchard heaters in raising the air temperature. It so happened that the heaters were not alight during the only severe frost which occurred that spring, for it was not forecast and in consequence no heating took place that night. On all occasions when the heaters were alight there was sufficient wind to keep the air stirred, thus preventing bad frost, so that in actual practice, heaters would probably not have been lighted. This same wind also blew away the hot air produced by the heaters and thus prevented any considerable heating-up

of the orchard air. In addition it should be mentioned that the heated area—one acre—was probably far too small for such conditions.

It is possible that the practice of orchard heating may be found to be most profitable in frost pockets, i.e. lakes of cold air undisturbed by wind, where the hot air would not be blown away and where the heaters would give their best performance.

Acknowledgments.

Special thanks are due to Professor Brunt (Imperial College of Science), Mr. E. G. Bilham (Meteorological Office) and Mr. E. L. Davies (Meteorological Department, Experimental Station, Porton) for their readiness to give advice and assistance, and to all those who actually took part in these investigations, especially those who volunteered to help in collecting records at night time. With the kind permission of the Director of the Meteorological Office, the instruments section has been most helpful in loaning apparatus ; this assistance has been indispensable. The author further wishes to thank Messrs. Geo. Monro and Messrs. Shell-Mex & B.P., Ltd., who lent apparatus, fuel-oil and a tank.

Summary.

The cause of the formation of a katabatic wind and some of its characteristics are briefly described. Emphasis is placed on the fact that a light breeze of relatively warm air, called here the upper wind, has always been found on hill tops on frosty nights. Some of the effects of the upper wind on the katabatic are outlined, and a means of utilizing the upper wind for the prevention of frost damage occurring on relatively high land is suggested.

Various methods are given for taking air temperatures accurately in orchards on frosty nights, together with reasons for accuracy in this respect.

When comparing the air temperature in a heated orchard with that outside it certain precautions should be taken, the chief of which is that the readings should be taken simultaneously.

The question of bud temperatures is mentioned and also that of the influence of wind on the effectiveness with which orchard heaters raise the air temperature.

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PHYSIOLOGY

APPLE TREES IN WATER CULTURE

By H. L. PEARSE

With the object of following the course of potassium, phosphorus and nitrogen absorption by different rootstocks, and rootstock-scion combinations it was decided to attempt to grow apple trees in water culture, so that by periodic analysis of the culture solution the desired information might be obtained. The advantage of the water culture method, if practicable, is that it allows of a succession of fairly easy and accurate determinations of the absorption without the destruction of the trees, so that a comparatively small number of trees may be used for experiment.

Barker (1920), in studying the root development, attempted to grow apple trees in water culture but reported indifferent success, the roots being very liable to fungal attack. The poor root growth was reflected in poor shoot growth. The same author (1921), using a sprinkler arrangement by which the roots were periodically moistened without being immersed in the culture solution, obtained more normal root and shoot growth, but reported that the growth was not equal to that of sand or soil cultures. He stresses the importance of aeration.

Colby (1933) gives a fairly comprehensive review of the literature of tree water culture from the time of Du Hamel du Monceau, 1755, down to the present time. Colby himself reports fairly good results with French Prune trees budded on Myrobolan rootstocks grown in water culture in four gallon crocks painted on the inside with black asphaltum. The trees were grown with their roots actually immersed in the solution, and aeration was supplied through glass tubes to the bottom centre of the jars. With a complete nutrient the trees made good root and shoot growth, and carried foliage of healthy colour ; but the total terminal, and diameter, growth was not equal to that produced by well-cared-for orchard trees of the same age in fertile soil.

The present report gives a short account of the behaviour of two types of unworked rootstocks in water culture at East Malling.

Material and Methods.

The trees used were two-year-old unworked rootstocks Malling Nos. II and V.

The solution used was that recommended by Wallace for the culture of fruit trees in sand, and contained the following ion concentrations : nitrogen, 110 p.p.m. ; potassium, 133 p.p.m. ; calcium, 88 p.p.m. ; magnesium, 40 p.p.m. ; sodium, 77 p.p.m. ; phosphorus, 52 p.p.m. ; sulphur, 52 p.p.m. ; with the addition of 10 p.p.m. of ferric citrate.

The trees were set up in the culture solution on 6th December, 1935.

In view of the promising results obtained by Barker (1921) using a sprinkler arrangement for supplying the roots with the nutrient solution, it was decided to try a similar arrangement, but made automatic so that the same solution could be continually sprayed and consequently the total amount of solution could be reduced. It was felt, however, that, as Barker suggested, the important factor in the sprinkler method might be the efficient aeration of the roots, and as Colby (1933) obtained fairly successful

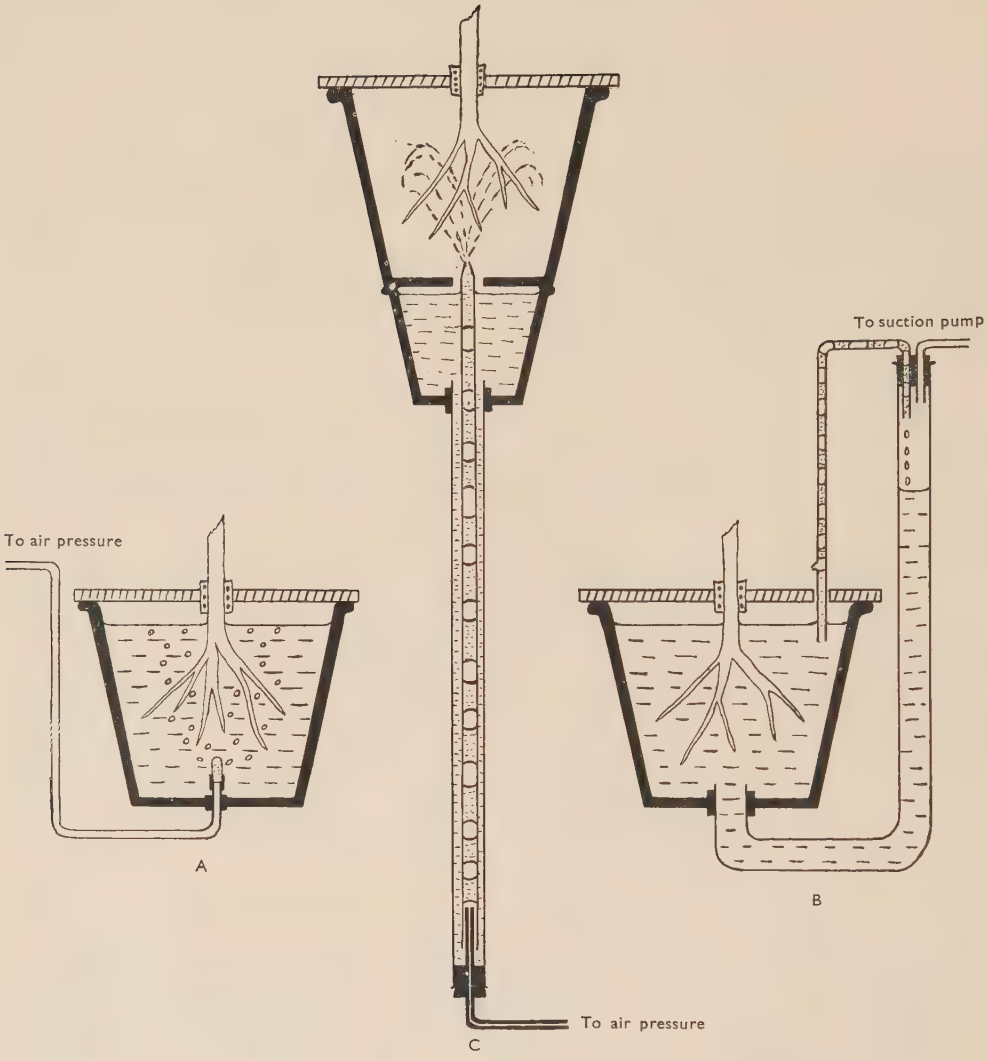


FIG. 1.
Methods of Aerating the Culture Solution.

growth of prune trees grown with their roots immersed in an aerated solution, it was thought that simpler methods of obtaining efficient aeration of the culture solution might be equally effective without going to the trouble of the rather complicated technique of spraying the roots.

Accordingly three methods of aerating the solution were tried, and these will now be described.

A. The Bubbling Method.

The trees were grown in 12-inch plant pots which had been coated with paraffin wax. Their roots were immersed in the solution, aeration being effected by glass tubes leading to the bottom centre of the pots. The air stream was broken up into fine bubbles by means of a small Alundun Thimble R.A.98. Each pot contained 8 litres of solution. Fig. 1A.

B. The Circulating Method.

Similar to A except that aeration was effected by removing the solution from the top of the pot aerating it, and then re-feeding it into the bottom of the pot. The solution was kept constantly circulating by means of a suction pump. Fig. 1B.

C. The Spray Method.

The roots were suspended in the pot and were constantly sprayed with the nutrient solution. The arrangement used is shown in Fig. 1C.

Each set consisted of four trees, two each of No. II and No. V. The pot covers were of wood treated with paraffin wax, the trees being held in place by loosely fitting corks. The air pressure for all three sets was obtained from a Reavel surgical pump which gives both a positive and a negative pressure simultaneously. The air was passed through a filter of animal charcoal to remove any possible contamination with oil vapour.

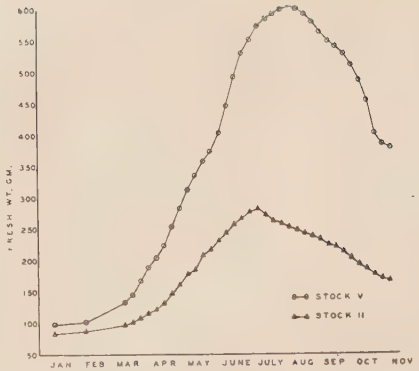
The trees were originally set up in 12-inch pots coated with paraffin wax as stated ; but it was found that fungi and bacteria accumulated on the wax, so trees in the bubbling and circulating methods were transferred to 4-gallon glazed earthenware culture pots on 22nd May and were thenceforward given 16 litres of solution. The solutions in A and B were changed every fortnight. The trees in the spray method were given 2 litres of solution changed every week. The trees were grown in a glasshouse with slight heat.

Behaviour of the Trees.

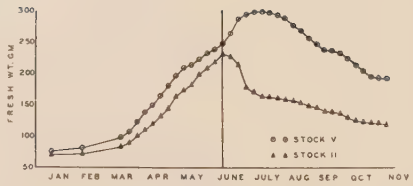
Root growth. On 30th December the following notes were made on the appearance of the roots of the trees. In the bubbling and circulating methods the roots were covered with a slimy fungus and were looking decidedly unhealthy. In the spray method the No. V's had already put out several new white roots ; the No. II's had not yet made any root growth but the roots in all cases were entirely free from fungal infection.

By 19th February all the trees had produced a considerable number of new white roots. In general the No. V's had made more root growth than the No. II's. All the cultures were now practically free from fungal infection.

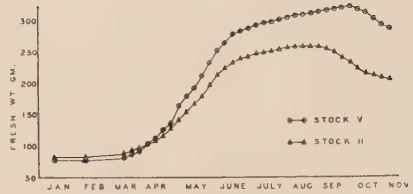
Aeration was stopped in the circulating method on 12th June, and within three weeks all root activity had stopped in the No. II's. Fungal infection re-appeared within two weeks on the roots of all these trees, and although the No. V's continued to put out a few new roots until the beginning of August, the root systems in all the trees were covered in slime and looked very unhealthy.



A. Bubbling Method.

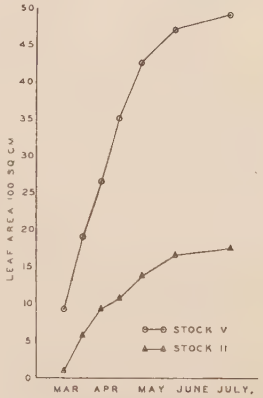


B. Circulating Method.

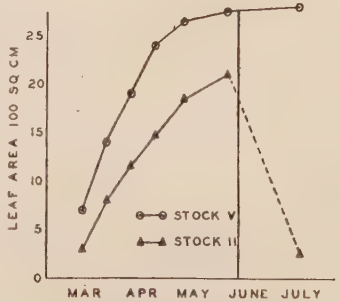


C. Spray Method.

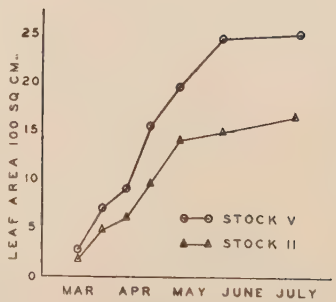
FIG. 2.
Average fresh weight throughout period of experiment.



A. Bubbling Method.



B. Circulating Method.



C. Spray Method.

FIG. 3.
Average leaf area.

In the bubbling method root growth continued in all the trees up to the end of August, and in the case of the No. V's to the middle of September. After that the root systems became blackened and there was no further sign of root activity. They were, however, free from fungal infection.

In the spray method root growth continued throughout the season, and at the beginning of November all the trees were still putting out new white roots. The new roots were always stouter and healthier looking in this group.

Shoot growth. By 25th February a large number of the buds were beginning to break on all the trees, the No. V's being rather more forward than the No. II's in this respect. By 26th March all the trees had made considerable shoot and leaf growth. On 2nd April yellowish patches were noticed on the leaves, especially of the trees in groups A and B. The yellowing was greatest in the youngest leaves. Leaf injections performed by Dr. Roach (4) showed that the yellowing was due to iron deficiency. This forms the subject of a separate article in this report. The amount of ferric citrate was then increased to 100 p.p.m. and this sufficed to cure the sprayed trees within a fortnight. In the bubbling and circulating methods, however, the deficiency symptoms still continued, and a cure was not effected until the trees were allowed to stand in a separate iron solution for twenty-four hours. The foliage then became normally coloured within a fortnight. Iron citrate, ferrous sulphate or ferric chloride were all used with success in concentrations of 100 p.p.m.

The fresh weights of the trees, and the areas of the leaves were determined periodically, and in Figs. 2 and 3 these values are plotted against time.

From these curves it is seen that in general the No. V's made more growth than the No. II's. When the fresh weights of the trees are beginning to decrease again this indicates the beginning of leaf fall. It is seen that the trees in the bubbling method grew faster than those in the spray method at first and this continued up to the end of June in the case of the No. II's and to the end of July in the case of the No. V's. However, this difference may have been partially due to the fact that these trees received less solution, and also to the fact that the spray occasionally failed, with a subsequent partial drying out of the roots.

It is seen that in all cases leaf fall was earlier in the No. II's than in the No. V's, and in the bubbling method started at the end of June on the No. II's and at the end of July on the No. V's. In the spray method the No. II's began to shed their leaves at the end of October, and the No. V's about the middle of November. It is seen that the curves for leaf area correspond closely with those for fresh weight. Of course it is realized that the number of trees used in these experiments is too small to allow of much stress being laid on these results, and they are merely given as an indication of the sort of growth obtained in water culture.

In the circulating method aeration was stopped on 12th June and leaf fall occurred within a fortnight in the No. II's and by the end of July in the case of the No. V's. There thus seemed to be considerable difference in the response of the two stocks to aeration.

Conclusions.

The water culture method allows comparatively easy and accurate study of absorption, when only a small number of trees is used; moreover the same trees can be used throughout the season. In addition it has the advantage that the fresh weights of the trees can be determined at any time.

Of course the trees are in an abnormal environment, but although a sand culture might more nearly correspond to the conditions of a sandy loam, a water culture might easily more closely resemble those of a heavy clay loam.

At any rate these results are definitely hopeful, and indicate that it is possible to obtain quite a good performance with apple stocks in water culture with a suitable technique.

The difference in the availability of the iron in the bubbling and spraying methods is interesting. It may be that in the culture solution iron is precipitated as iron phosphate, and that the spray method brings this precipitate into contact with the roots whence it can be absorbed by the roots, whereas in the other methods it remains at the bottom of the pot.

The difference in the response of the two stocks to aeration was very striking, and such differences may well help to explain the variability of stocks under diverse soil conditions.

In conclusion the author wishes to thank the Director of the Long Ashton Research Station, Professor B. T. P. Barker, for his kindness in supplying details of his sprinkler method of growing fruit trees in water culture, Dr. T. Wallace of the same Institute for his valuable advice on the composition of the nutrient solution, and Dr. W. A. Roach for his kind interest and help throughout the course of this experiment.

Summary.

1. The technique for growing apple trees in water culture is described, with special reference to the methods of aerating the nutrient solution.

2. Three methods of aerating the solution were tried.

A. Air was bubbled through the solution.

B. The solution was constantly circulated and aerated.

C. The roots were automatically sprayed with the solution.

3. The trees used in this experiment were two-year-old unworked Malling rootstocks Nos. II and V. Records of fresh weight, and leaf area showed that in general the No. V's made more growth than the No. II's, and in all cases leaf-fall was earlier in the No. II's than in the No. V's.

4. The trees in the spray method showed the most nearly normal root growth throughout the season, and defoliation also occurred much later with this treatment than with the bubbling method.

5. The ability of the trees to obtain sufficient iron for healthy foliage colour from the same nutrient solution was found to vary with the method of aeration. The iron (which was supplied as ferric citrate) was more readily available to the trees in the spray method than in the other methods.

6. No. II rootstock was much more susceptible to lack of efficient aeration than No. V.

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SOME OBSERVATIONS ON THE TIME OF DEVELOPMENT OF THE FRUIT, SEED AND EMBRYO IN APPLE

By P. K. SEN

Introduction.

It has been suggested by the various authors that fruit-bud formation is favoured by a high carbohydrate-nitrogen ratio. On the other hand it is known that the growth and development of the embryo in the seed requires more nitrogen than carbohydrate. Knowledge of the relative times of fruit-bud formation and embryo growth would, therefore, be of interest in connection with the problem of biennial bearing.

The time of fruit-bud formation in the apple in England is known within reasonable limits as the result of some unpublished work at this station and the work of Gibbs and Swarbrick (6).

Generally fruit-bud initiation begins towards the end of June and active differentiation takes place during July and early August.

Time of embryo development, on the other hand, seems to have received little attention in the apple though it has been studied in some detail in stone fruit by Connors (3), Blake (1), Lilleland (4, 5), Tukey (7, 8) and others. These authors have shown that development of stone fruit passes through three well-marked stages: (1) Rapid growth after fertilization due mainly to increase in size of stone. The nucellus and integuments grow rapidly to full size, but the embryo does not start active growth until near the end of this period. (2) A period during which the growth of fruit is retarded but the stone hardens and the embryo rapidly reaches full development. (3) Renewed rapid development of the fruit to maturity.

In an attempt to fill this gap some observations have been made on the course of fruit, seed and embryo development in the apple. Although these observations are rather fragmentary and do not cover the whole period, they seem of sufficient interest to be put on record.

Material.

Two varieties of apples were used for this study: (1) Beauty of Bath, a diploid, fruit maturing about 90 days after full bloom, and (2) Bramley's Seedling, a triploid, fruit maturing after about 150 days. The observations were carried out in the summer of 1936 on three trees of each variety, all growing on the same plot, and all of the same age (twenty-two years). The Beauty of Bath were in full bloom about 6th May and the Bramley's Seedling about 11th May.

Sampling.

As the primary object was to determine the stage of the embryo at about the time of fruit-bud initiation, samples of fruitlets were collected at about weekly intervals from 2nd June until 30th June. In addition, a final sample of mature fruits was taken at the harvest time.

The first sample taken on 2nd June consisted of fifty representative fruitlets per tree ; only those that appeared to be normally set were included. The 150 from the three trees of each variety were mixed together and twenty-five, taken at random, were measured for fruit size and preserved in formalin-alcohol for later dissection ; the rest of the fruitlets were discarded.

As the fruitlets became progressively larger in successive samples, the number of fruitlets collected per tree was reduced. Thus twenty-five fruitlets per tree were collected at the second sampling on 7th June, and twenty-five, per variety, selected at random for measurement.

In the third, fourth, and fifth samplings, taken on 15th, 22nd and 30th June, respectively, only ten fruits per tree were collected and ten per variety used for measurements. The bigger fruits were split into halves or quadrants before preserving in formalin-alcohol.

The sixth sample, i.e. the one at harvest, was taken on 8th August for Beauty of Bath and 21st October for Bramley's Seedling in the same manner as for the previous three samples.

Method.

For the fruit-size the maximum diameter (breadth) was measured in cm. by a Vernier caliper.

The developing fruits from each sample of fruitlets preserved were dissected out and a random sample of twenty-five seeds selected for measurement of length and breadth. A piece of mm. squared paper pasted on a slide was used as a rule. Each seed in turn was placed in this rule and measured under a low power dissecting microscope to the nearest quarter division (judged by the eye).

The embryos from the seed measured were dissected out and their lengths and breadth determined. Those from the mature seed of the final sample from both varieties, and from the sample of Beauty of Bath gathered on 30th June, were measured in the same way as the seed, but the embryos from Bramley's Seedling seeds on 30th June and from the seed of earlier samples from both varieties being too small to measure on mm. paper, were measured under a higher power with an eye-piece micrometer.

The Data.

The data obtained are summarized in Plate 1, Figs. A-E, and Table I. The plate shows the size of the seed, and the size and condition of the embryos at the various times. The table gives the actual mean dimensions of the fruit seed and embryos.

Table I.

Beauty of Bath.

Sample Date		1 2.6.36.	2 7.6.36.	3 15.6.36.	4 22.6.36.	5 30.6.36.	6 8.8.36.
Fruit—	diameter cm.	1·1	1·9	2·5	2·9	3·0	4·5
	calculated volume $cm.^3$	0·7	3·3	7·6	12·1	14·2	47·8
Seed—	length mm.	2·4	3·5	5·4	7·2	7·2	7·6
	breadth mm.	1·6	2·5	3·3	4·0	4·3	4·8
Embryo—	length mm.			0·2	0·55	2·1	6·2
	breadth mm.			0·3	0·38	1·3	3·4

BRAMLEY'S SEEDLING.

Sample Date		1 2.6.36.	2 7.6.36.	3 15.6.36.	4 22.6.36.	5 30.6.36.	6 21.10.36.
Fruit—	diameter cm.	1·0	1·6	2·8	3·5	3·7	6·1
	calculated volume cm.^{3}	0·5	2·1	10·9	22·5	25·5	119·2
Seed—	length mm.	2·5	3·6	6·1	7·8	8·2	8·7
	breadth mm.	1·4	1·9	3·0	3·6	3·9	4·2
Embryo—	length mm.			0·23*	0·52	1·0	6·6
	breadth mm.			0·17	0·43	0·7	3·4

* Including suspensor.

In Figs. 1 and 2 the mean diameter of the fruit and the mean lengths of the seed and the embryo, expressed in each case as a percentage of the final size, at fruit maturity, are graphically represented.

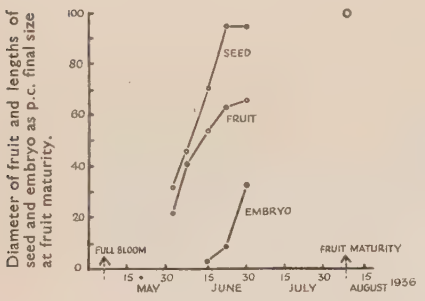

FIG. 1.

BEAUTY OF BATH. Mean diameter (breadth) of fruit and mean lengths of seed and embryo at the various dates during the month of June, *expressed in each case*, as percentage of the final size at fruit maturity.

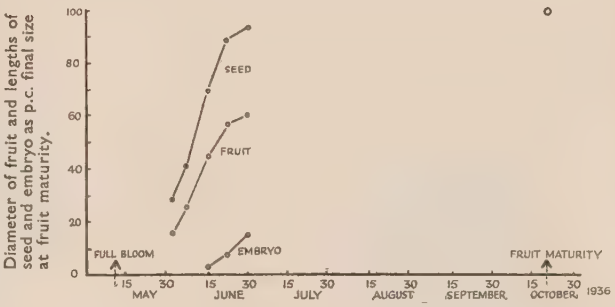

FIG. 2.

BRAMLEY'S SEEDLING. Mean diameter (breadth) of fruit and mean lengths of seed and embryo at the various dates during the month of June, *expressed in each case*, as percentage of the final size at fruit maturity.

In the first two samples the embryos were too small to be dissected out. In the third sample (15th June) the embryos were of appreciable size, but owing to difficulty of dissection only five from each variety were removed from the seed. The embryos of Bramley's Seedling still consisted of a small undifferentiated mass of cells but those of Beauty of Bath were somewhat more advanced (Plate 1, Figs. B and C).

The embryos from the fourth sample (22nd June) were dissected from the twenty-five seeds of each variety. All those of Beauty of Bath showed differentiation into radicle and cotyledons but only six out of twenty-five of the Bramley's Seedling embryos had reached this stage (Plate 1, Figs. D and E).

In the fifth sample (30th June) differentiation was complete in both varieties but the embryos of Beauty of Bath were considerably larger than those of Bramley's Seedling.

In the final sample taken from seeds of matured fruit (Beauty of Bath, 8th August, and Bramley's Seedling, 21st October) all the twenty-five embryos were normal in Beauty of Bath but nine out of the twenty-five in Bramley's Seedling were aborted.

Discussion.

The data recorded here indicate that the seed (nucellus and integuments) develops very rapidly during the month of June, reaching nearly the full size by the end of the month. In spite of the very big difference in the length of the period until fruit maturity in the two varieties, the seeds in Beauty of Bath seem to reach full size only a week earlier than those of Bramley's Seedling. As the latter bloomed about a week later than Beauty of Bath the time from blooming seems to have been the same in both cases.

The fruit grew rapidly during the month of June but it had only reached about two-thirds its final diameter (66 per cent. in Beauty of Bath and 60 per cent. in Bramley) at the time when the seed was more or less full size. During the last week in June the seed showed retardation in growth.

The embryo, on the other hand, made little progress towards differentiation until the middle of June. During the latter half of the month, however, it made rapid growth ; but by the end of the month it had reached only about 33 per cent. of its final size in Beauty of Bath, and about 15 per cent. in Bramley's Seedling.

The fruit, seed and embryo in apple, in so far as they have been studied here, indicate a more or less similar periodicity in development to that found in stone fruits (1, 3, 4, 5, 7 and 8).

The seeds in the fruit of apple seem to reach full size well before the time of fruit bud differentiation.

Incidentally, it may be mentioned here that the considerable embryo abortion in Bramley's Seedling is very probably related to the triploid nature of the variety, as also reported by Bryant (2) in some other triploid varieties of apples.

In conclusion the writer wishes to express thanks to the Imperial Bureau of Fruit Production for help in looking up the literature on the subject.

Summary.

The size of fruit, seed and embryo in Beauty of Bath and Bramley's Seedling were determined at approximately weekly intervals from 2nd till 30th June and compared with their sizes in matured fruit, during the season of 1936.

The seed reached nearly full size by the end of June. At this time the fruit had reached only two-thirds of its final width.

The embryo started rapid development in the middle of June.

The embryos of the early maturing Beauty of Bath were consistently more advanced than those of Bramley's Seedling.

The relative periods of development of seed, fruit and embryo, in so far as they have been followed, are consistent with those described for stone fruit.

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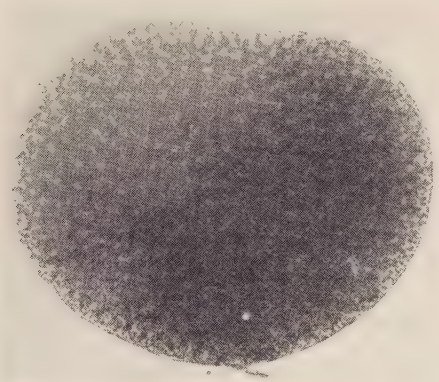
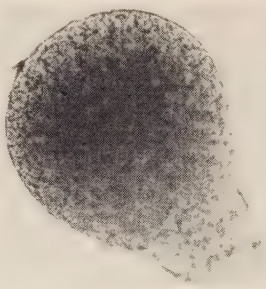
(3) Connors, C. H. "Growth of the fruit of the peach." N. J. Agri. Sta. Ann. Rep., **41**, 82, 1919.

A. Seed and embryo (*natural size*) of Beauty of Bath (above) and Bramley's Seedling (below), on different dates in June and at harvest.



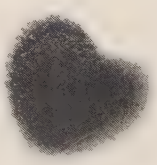
B. Beauty of Bath.



C. Bramley's Seedling.

Embryo on 15th June (× 250)

D. Beauty of Bath.



E. Bramley's Seedling.

Embryo on 22nd June (× 75)

(4) LILLELAND, O. "Growth study of the apricot fruit." Proc. Amer. Soc. Hort. Sci., **28**, 237, 1931.

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BIOCHEMISTRY

THE INJECTION OF SINGLE INTERVEINAL AREAS OF LEAVES FOR DIAGNOSIS OF MINERAL DEFICIENCY

By W. A. ROACH

Introduction.

The most reliable method of diagnosing mineral deficiency in plants is actually to administer the minerals to some of the plants and compare their development with that of untreated ones. Seeing that the improvement is at first imperceptible and increases in the course of time to a maximum, the rapidity of the diagnosis increases as smaller and smaller differences can be detected.

It is difficult to detect a small change in average colour of a whole tree both because there is some degree of variation between the colour of its various parts and because it cannot be separated from the compared tree by a sharp line. This difficulty was to a large extent met by the leaf injection method already described (1) in which, instead of treating a whole tree or group of trees, a single leaf was treated and compared with a similar one close at hand on the same tree. Iron deficiency was diagnosed by this method in ten days. The method to be described here is even more rapid, and much more sensitive. A single interveinal area of a leaf is injected with a solution of the substance and this area is watched in comparison with the areas on either side of it and each separated from it by a secondary vein only. Hence, the treated area initially is of exactly the same colour and texture as the two compared areas and separated from them by little more than ruled lines, and in consequence very small changes in colour, texture and rate of growth can be detected.

Procedure.

The injection may be carried out in two ways, the first being suitable for apple, or larger, leaves and the second for smaller leaves.

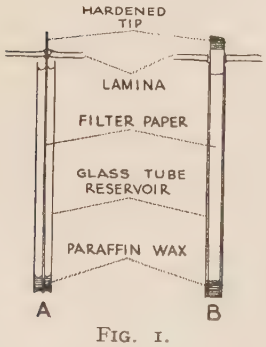

Fig. 1.
Apparatus for interveinal leaf injection. B at right angles to A.

The first method is illustrated diagrammatically in Fig. 1. The liquid, held in a reservoir, is drawn up a filter paper "wick" which passes through an incision made in the leaf. The "lips" of the incision clip the wick, which in turn supports the reservoir. A film of liquid connects the cut tissues with the wet filter paper. The tissues absorb liquid from the film and liquid travels up the filter paper to make good the loss.

The reservoir consists of a thin-walled glass tube* 1·5 mm. in diameter and about 3 cm. long. The narrower end of a strip of a toughened filter paper (Whatman No. 54),

* Tubes supplied by Messrs. British Drug Houses for their Capillator Sets are of suitable diameter and wall thickness.

1·5 mm. wide at one end and tapering to 1·0 mm. in 10 cm., is drawn through the glass tube until the wider end just fits the tube. The narrower end is cut off flush with the end of the glass tube and the wider end is cut off about 0·3 cm. above the end of the glass tube. The surface of paraffin wax kept molten at 100° C. is just touched with the former end of the glass tube, so that the wax forms a tiny plug which fills the end of the tube and fixes the end of the filter paper strip without rising appreciably in it. The tip of the protruding end of the filter paper is dipped momentarily into Durofix solution diluted with 1½ volumes each of ether and alcohol so that the top mm. is permeated with the solution. On drying, this treated portion of the paper remains tough after being moistened.

An all-glass hypodermic syringe (without the needle) is filled with the liquid. A piece of glass tubing drawn out to a capillary is connected to it with a short piece of rubber tubing ; the capillary is inserted to the bottom of the reservoir tube, which is filled with the liquid, the capillary tube being withdrawn during the operation. The operation may be carried out simply with a glass tube drawn out to a capillary but the above method is much easier to carry out.

The incision is made with the scalpel illustrated in Fig. 2 ; it is constructed by breaking off a conveniently shaped piece of safety razor blade, inserting its base into the split end of a large-size Bryant & May's match stalk and strengthening the union with sealing-wax.

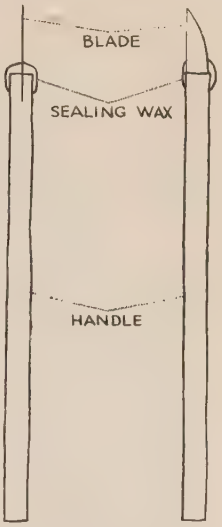

Fig. 2.
Scalpel for interveinal injection.

Position of the Incision.

The incision is made so as to be about equidistant from the two secondary veins and the main vein, as shown at A etc. in Fig. 3.

Manipulation. Leaves are easily damaged unless some such procedure as the following is adopted. The centre, third and fourth fingers of the two hands are placed tip to tip behind the leaf, which is held between the thumb and forefinger of the left hand. With the scalpel, held between the thumb and forefinger of the right hand, an incision is made of length equal to the width of the "wick" (i.e. 1·5 mm.), in the under side of the leaf about equidistant from two neighbouring secondary veins and the midrib, as shown at A, etc., in Fig. 3. The hardened end of the protruding piece of filter paper, held in pointed forceps, is pushed through the incision, and finally pulled until the top of the reservoir nearly touches the leaf. If the operation has been carried out properly the edges of the incision hold the paper sufficiently firmly to support the reservoir.

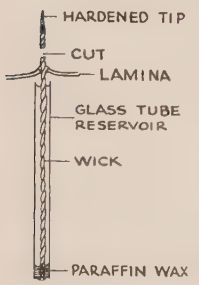

Fig. 4.
Apparatus for interveinal leaf injection.

The second method is even simpler than the first and is applicable to smaller leaves. In it the filter paper "wick" is replaced by a piece of darning cotton which serves the same purpose. The method is illustrated in Fig. 4.

A 5 cm. length of darning thread is broken off. The end is pointed by rolling between the finger and thumb as if for threading a needle, and dipped in "Durofix" solution diluted with 1½ volumes each of ether and alcohol and allowed to dry. The thread is then passed through a piece of glass tubing similar to that used for method 1 so that its untreated end is flush with one end of the tube.

This end is dipped momentarily in high melting point paraffin wax kept molten at 100°C. so as to plug it and fix the end of the thread to it with wax. The reservoir is filled in the same way as in method 1. The hardened end of the thread is pushed through the lamina at the desired point, pulled through until the top of the reservoir nearly touches the lamina ; and finally the excess thread is cut off as shown in the figure.

Distribution of Injected Substance.

This shows the distribution of patent blue injected through incisions made at points in alternate interveinal areas. The areas injected at the end of four hours are shaded heavily and the edges of those invaded in the following nineteen hours are shown by dotted lines. Nothing was done to the remaining interveinal areas on the left hand side of the leaf, but those on the right hand side were injected with water. The water injections had no appreciable effect on the distribution of the patent blue injections. Such injections, therefore, may be carried out on the assumption that well-developed secondary veins are practically impassable barriers for at least half their length, whether the next interveinal areas are injected or not. Even when the secondary veins are crossed there is never any uncertainty as to which injection was responsible for the colour or other change, because the injected area is always continuous and is never sub-divided, and always has within it the incision through which the injection was made. The pair of areas between the leaf-stalk and the first secondary veins and the terminal quarter of the leaf are less suitable for interveinal injection than the remainder of the leaf since the injected areas are less clearly separated.

Duration of Injection. The above and similar experiments have proved that unless the injection is allowed to proceed for some time the injected area does not extend far along the secondary veins. The effect of the injection can be observed best when injected and uninjected areas are separated sharply along as great a distance as possible. These conditions were satisfied in the experiment when the injection had proceeded for 4 hours ; the area then invaded is shaded in Fig. 3. At this stage the secondary veins on either side of the incision formed a sharp boundary for rather more than half their length between injected and uninjected areas. The limits of permeation at the end of 24 hours are shown by dotted lines. It will be seen that if the injection is allowed to proceed too long the injected liquid tends to creep beyond the secondary veins and the divisions between injected and uninjected areas cease to be so definite as when the secondary veins themselves constitute the boundaries. The optimum duration of injection varies somewhat from one type of leaf to another and according to the climatic conditions ; consequently, to obtain the sharpest contrasts preliminary experiments should be carried out with dyes ; but for leaves of apple, pear, strawberry and shasta daisy, a duration from 7 to 12 hours has been found satisfactory.

The injected substance tends to accumulate in greatest amount near the incision and the amount decreases as the distance from the incision increases. Consequently, even if the tissues near the incision are damaged through too great an accumulation of substance others somewhere between the damaged ones and the limits of the injection are almost certain to receive the optimum dose.

Time of Detection of Response to Injection. As already pointed out, the conditions under which the treated and untreated areas of leaf are compared are nearly ideal in that they are separated only by a narrow secondary vein and in that the comparison can be made along both sides of the treated area ; in these circumstances the faintest colour change is readily detected which would be quite impossible of detection by other methods, as, for example, when comparison is made between whole plants, the individual leaves

FIG. 3.

of which usually show considerable variation in colour. The quickest response to injection so far observed was given by an injection of a 0·05 per cent. iron citrate solution into a chlorotic apple leaf (see p. 147), when a slight but quite definite green tint was observed three days after injection. The green increased in intensity for a further seven days. In other experiments seven days have elapsed before the response has become definitely discernible.

Effect of the Age of the Leaf. The limited experience so far obtained with this method suggests that a half-grown leaf is the best. Responses have been obtained with immature leaves when mature ones have given no visible response. Further, when such immature leaves have been injected, in addition to the improvement in colour, there has sometimes been observed a greater growth of the injected as compared with the uninjected areas; the greater growth of the injected areas has resulted in their being raised above the flat surface of the rest of the leaf to accommodate its relatively greater area, and the leaf as a whole has presented a puckered appearance.

Substances Injected. Because of the striking colour change brought about by the injection of iron compounds into one type of chlorotic leaf most attention has so far been paid to this element, but experiments are being carried out on other elements, including the major nutrient ones

Kinds of Leaves. The above methods have been applied successfully to apple leaves and strawberry leaflets, the venation of both of which is reticulate—pinnate, but Mr. H. Hill, in unpublished work, has found that they are not applicable to tomato leaves.

Summary.

A single interveinal area of a leaf may be injected with a suitable nutrient solution. A small incision, equidistant from the main vein and the two secondary veins, is kept moist for about seven hours with the liquid held in a reservoir, which is described.

Iron shortage has been diagnosed in three days. At the end of this time the injected area was perceptibly greener than the ones on either side of it.

Reference.

Roach, W. A. "Leaf injection." E. Malling Res. Sta. Ann. Rep. for 1935 (1936), 134-6.

IRON " SHORTAGE " CHLOROSIS IN APPLE TREES GROWN IN WATER CULTURE

By W. A. ROACH

In a report on experiments in which apple trees were grown in water culture, Dr. H. L. Pearse mentions that the trees became chlorotic (1). As I am particularly interested in chlorosis he allowed me to carry out on his trees the experiments which form the subject of this present report.

Symptoms.

The leaves showed a striking gradation of symptoms. At the base of each shoot there was one leaf of a perfectly healthy green colour. Next came two, three, or even four, leaves each of a lighter green than the one below it ; but even the lightest one could hardly be described as chlorotic in the generally accepted sense of the term. Above these was a leaf with a more or less continuous area of lighter green than the rest of the leaf ; this area stretched from the leaf-tip along the margin and reached half to three-quarters the way towards the base. This lighter green area in some such leaves had small extensions between the veins ; and the area was sometimes of such a light green colour as to justify being called chlorotic. In the succeeding two or three leaves the extensions had spread in each leaf nearer to the main and side veins than in the one immediately below it until only a narrow band of green was left round the main and larger veins. In such leaves the chlorotic areas appeared to be quite destitute of green. Leaves at the apex of a few shoots were completely chlorotic, lacking even the narrow green bands around the veins just mentioned.

Culture Solution.

As stated by Dr. Pearse in his report, the culture solution employed was that recommended by Dr. T. Wallace, as a result of his experience in growing apple trees in sand, except that the iron was given entirely as ferric citrate (instead of ferric chloride, with the addition of ferric citrate when chlorosis appeared).

At the writer's suggestion the iron was added in this organic, instead of the more usual inorganic form, because the results of experiments in which plums were grown in sand with solutions, to which iron was added as ferric chloride, raised the question as to whether the plums were able to make proper use of it when added in this form to the culture solutions (2). Further, in the present experiments the volume of solution was reduced to a minimum so that a maximum change in percentage composition should result from the trees growing in it ; in these circumstances the effect of any shortage, or lack of availability, of the iron would be enhanced. The iron was added as ferric citrate in the hope that, being less readily precipitated by phosphates, it would be more readily available to the trees. When, therefore, the trees became chlorotic there seemed to be no reason for suspecting a shortage, or a lack of availability, of iron rather than of a number of other elements, such as copper, magnesium, manganese, sulphur and zinc, since a shortage of any of these elements has been proved to lead to a chlorosis of the same general character as that just described.

Diagnostic Injection Experiments.

The diagnosis of the cause of the chlorosis was attempted by injecting compounds containing the nutrient elements by the interveinal leaf method (3) p. 142. In view of the abnormal conditions under which the trees were growing it seemed safer to test the elements systematically rather than to confine attention to those, a shortage of which commonly leads to the observed symptoms. The results of the injections carried out are summarized in the following table :

Solution.	No. of areas injected.	Result.
0·05% Ferric citrate	4	The foliage became green.
0·05% Ferrous sulphate	1	The foliage became green.
0·05% Ferric citrate, + 0·5% Urea	1	The foliage became green.
0·5% Urea	4	No apparent effect.
0·5% Potassium di-hydrogen phosphate	2	No apparent effect.

A slight but definite change in colour was apparent the third day after injection in all six areas which had been treated with iron, and within a week they had taken on their normal green colour. All these injections were carried out on leaves which had not finished growing. At least two of the areas injected with iron salts became raised in folds, showing that they had grown faster than the surrounding uninjected areas. There seemed little doubt, therefore, that faulty iron metabolism was the cause of the chlorosis.

This conclusion was supported by the fact that when the amount of ferric citrate in the culture solution was increased from 10 p.p.m. to 100 p.p.m. the trees whose roots were sprayed with the solution took on a normal green colour within a fortnight. Those in the aerated and circulated solutions, however, were not cured.

Effect of Iron Salts Alone.

In separate experiments the aerated and the circulated culture solutions were replaced by 100 p.p.m. solutions of either ferric citrate, ferrous sulphate or ferric chloride for one day, after which solution of the original composition was replaced. This treatment led to the trees taking on their normal green colour within a fortnight. All were equally effective and no differences were observed. Little doubt, therefore, remains that faulty iron metabolism was the cause of the chlorosis.

The Condition of the Iron in the Solutions.

The trees growing in the aerated, and those in the circulated, solutions, both became chlorotic before those, the roots of which were sprayed with the solution ; and we have seen that increasing the ferric citrate in the solution restored the green colour to the foliage of the sprayed trees but not the others. Both these facts suggest that the iron was rendered unavailable to the trees more rapidly in the aerated and circulated solutions than in the sprayed one. No explanation can be given at present for this fact.

The culture solutions, after they had been bathing the roots of the trees for a fortnight, had usually lost the yellow colour due to the ferric citrate and had become colourless and had deposited a precipitate of ferric phosphate, but on at least one occasion there was no precipitate and a comparison with a freshly made solution showed

that there was little diminution of yellow colour ; yet the tree growing in this solution was chlorotic. We have seen that after one day only in a solution containing an iron salt alone of similar concentration trees recovered their green colour. This suggests that a solution, which still shows the yellow colour of the ferric salt, which is free from precipitate or opalescence and in which, consequently, the iron must be in at least colloidal solution, need not necessarily be a satisfactory source of iron to plants ; but more work is necessary on this point. The fact that ferric phosphate is eventually precipitated raises the question whether an earlier stage is the combination of ferric citrate and the phosphate to form either colloidal ferric phosphate or some more complex colloidal substance.

Discussion.

The experiments prove that availability of iron is of particular importance in the growth of apple trees in water culture. The two simplest ways of ensuring that the trees obtain enough iron are either to use culture solutions which are more acid or else to allow the trees to absorb the iron and the phosphate separately. In the later experiments just described the culture solution, from which iron had been omitted, was replaced by a solution of an iron salt for one day each fortnight when the culture solutions were renewed. A simpler, and probably equally effective, method would be to omit the phosphate when changing the solutions and to add it one day later when the trees have had time to absorb all the iron which they require until the solution is again renewed.

As stated earlier in this paper, the leaves on each shoot showed an almost continuous gradation of colour between the basal one, which was of a normal green colour, and the terminal ones which were quite free from chlorophyll. In all probability the basal leaf owed its greenness to the iron already in the tree when it was transferred to the solution and, as this iron was used, or even precipitated in unavailable form by the phosphate absorbed, each leaf which expanded would have less iron for the formation of its chlorophyll than the one below it.

Of particular interest is the fact that between the healthy basal leaf and the first one showing typical chlorotic symptoms there were two or more leaves of a light unhealthy green colour. Leaves of similar appearance are commonly seen in plantations in various parts of Kent. In another communication reasons will be given for suspecting that faulty iron metabolism is a common cause of the unhealthiness of some of the foliage in commercial plantations.

Acknowledgment.

This work was done in co-operation with Dr. H. L. Pearse, to whom the writer is grateful for placing material so freely at his disposal.

Summary.

1. The cause of a chlorosis in apple trees, grown in a culture solution containing 10 p.p.m. ferric citrate, was shown by the interveinal method of leaf injection to be due to faulty iron metabolism.

2. The foliage of the trees was afterwards kept in a healthy green condition by administering an iron salt in pure solution once a fortnight.

3. Leaves, which would not be described as chlorotic, but which were of a light unhealthy green colour took on a normal healthy green colour as a result of this iron treatment.

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(1) Pearse, H. L. "Apple Trees in Water Culture." E. Malling Res. Sta. Ann. Rep. for 1936 (1937), 131-6.

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(3) ——— "The injection of single interveinal areas of leaves for the diagnosis of mineral deficiency." E. Malling Res. Sta. Ann. Rep. for 1936 (1937), 142-5.

LEAF-STALK INJECTION FOR THE DIAGNOSIS OF MINERAL DEFICIENCY

By W. A. ROACH

Introduction.

When a leafy shoot is allowed to absorb a harmless liquid through the stump of a leaf-stalk after the leaf has been cut off, the liquid is distributed amongst the other leaves on the shoot in a regular manner. In some of the leaves the liquid permeates the blade on one side of the main vein leaving the other side unaffected. The injected and uninjected areas, being separated sharply by the main vein, may be used for watching the effect of the injected liquid on the leaf; and the method may be used for diagnosing mineral deficiency by using solutions of suitable mineral salts. The following experiment will illustrate the method.

A leaf near the base of a current year's apple shoot was cut off so as to leave a short length of leaf-stalk attached. To this was connected by bicycle valve tubing the drawn-out end of a small test tube, the upper end of which was fixed to the stem with lead wire (or rubber surgical tape). The method is illustrated in Fig. 1 which is of a photograph of a later experiment. The tube was filled with a 0·5 per cent. aqueous solution of acid fuchsin with a hypodermic syringe, care being taken to wet the cut end of the leaf-stalk and to expel all air from the narrow tubing. There was a perceptible coloration of parts of leaves in a few minutes and the distribution could be mapped in about fifteen minutes; the intensity of this coloration continued to increase but there was no further spread of the dye at the end of a day.

Table I.

Leaf.		Fraction of leaf blade injected.	Angular distance from injected leaf-stalk.
Above injected leaf-stalk	10	Slightly more than half	2/8
	9	Slightly less than half	3/8
	8	Whole	0
	7	Slightly less than half	3/8
	6	Slightly more than half	2/8
	5	Nearly whole	1/8
	4	None	4/8
	3	Nearly whole	1/8
	2	Slightly more than half	2/8
	1	Slightly less than half	3/8
Injected leaf-stalk	0		
Below injected leaf-stalk	**1**	Slightly less than half	3/8
	2	Slightly more than half	2/8
	3	Nearly whole	1/8
	4	None	4/8
	5	Nearly whole	1/8

The resulting distribution of the dye is shown diagrammatically in Fig. 2, which is drawn as if the leaves had been detached from the shoot and attached to points on a phyllotaxis diagram corresponding to their positions on the stem. They are also expressed in a different form in Table I. The fraction of the area of the leaf permeated by the dye decreased as its angular distance from the injected leaf-stalk increased; the

leaf " above " it, No. 8, was permeated throughout its whole area, whereas leaf No. 4 up the spiral, which is on exactly the opposite side of the stem to the injected leaf-stalk, was not reached by the dye at all. The corresponding leaf down the spiral, No. **4**, was also quite free of dye. Leaves 3, **3** and 5 (i.e. the third leaf up, the third leaf down, and

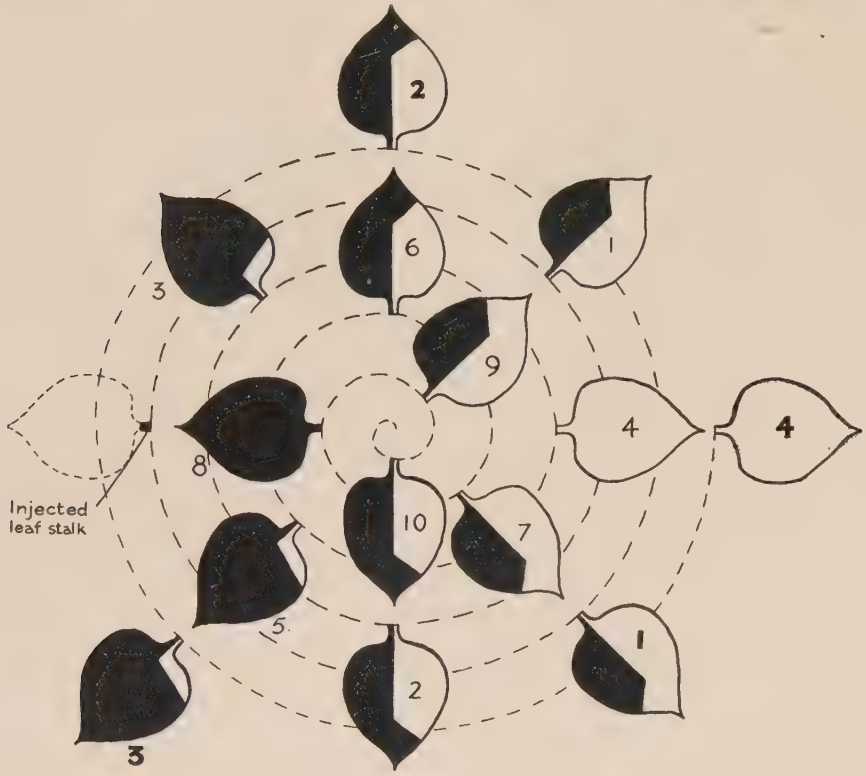

Fig. 2.

the fifth leaf up the spiral) which were distant only 1/8 circumference from the absorbing leaf-stalk were permeated except for a small area at the base of the blade on the side remote from the absorbing point. Leaves, 2, 10, 6 and **2** (distant 2/8) were permeated over slightly more than half their area ; and leaves 1, 9, 7, **1** (distant 3/8) were permeated over slightly less than half their area. The diagram makes the fact clear that the permeated part of a leaf always stretched as an undivided area extending from the base of the blade on the side nearer to the absorbing leaf-stalk and keeping to that side of the midrib until the leaf tip was reached ; no other part of the leaf was permeated unless the proximal basal area was permeated. Conversely, a small basal area on the opposite side of the leaf was never permeated unless the remainder of the leaf was also permeated. Other experiments showed that the actual fractions of the leaf areas permeated could be decreased at will below that shown in Fig. 2 by making the cut nearer the leaf tip. If not more than one-fifth of the main vein be removed when the cut is made, no injected liquid escapes into other leaves. Hence, as the amount of main vein removed increases from one-fifth to the whole blade together with most of the leaf-stalk, so the permeated areas of other leaves on the shoot increase from nothing up to those shown in Fig. 2. As the amount removed from the

absorbing leaf increases, so, for example in leaf 3, the permeated area increases. At first a small basal area on the proximal side of the main vein is affected, the effect then spreads up the proximal side of the vein, round the tip of the leaf and down the distal side until only a small area such as that shown in Fig. 2 is left unaffected.

In eight experiments in which the cut was made half-way along the leaf-stalks, four with 0·5 per cent. acid fuchsin and four with 0·5 per cent. patent blue, the resulting distributions were practically identical.

In experiments in which a leaf-stalk near the middle of the current year's shoot was selected, the liquid travelled rather less freely downwards than upwards, actually reaching the tenth leaf upwards and only the fifth one downwards. In other experiments in which the leaf-stalks nearer the tip of the shoot were selected, so that the upward movement was limited by the number of leaves above the absorbing leaf-stalk, the downward movement tended to increase rather than decrease ; when leaves which had just become fully expanded were used movement downwards was actually greater than that upwards. Closely similar results were obtained with shoots which had finished extension growth. The distribution of dye in leaves which were still folded followed the same rules. These facts show that liquids may be injected by these methods with considerable confidence as to what the actual type of distribution will be ; and experiments with colourless liquids can be designed so that the most sensitive leaves, i.e. the youngest, are injected in such a way as to be of the most use for diagnosis. Perhaps the most generally useful arrangement is to inject the leaf-stalk of the youngest leaf which is stiff enough for the rubber tubing to be attached to it easily ; the two leaves above it are usually still unfolding, and consequently are likely to respond fully to any nutrient supplied; and there are in addition two leaves below, either or both of which may not be too old to show some degree of response. In all four of these leaves the basal proximal quarter is injected and the corresponding distal quarters are uninjected. In the basal halves of these leaves, treated and untreated quarters are divided sharply from each other by the main vein. This is an almost ideal arrangement for showing any small difference in colour, rate of growth, etc. Already it has proved of great use in diagnosing faulty iron metabolism.

A total of sixteen injections of 0·05 per cent. solutions of iron citrate and ferrous sulphate have been carried out by Mr. Levy and the author (see p. 155) on apple trees in the plantations. The distribution of both the bronzing, which resulted in a few injections from slightly excessive doses, and the increased depth of green, when observed in experiments, followed the same laws as those governing the distribution of dyes.

This type of injection has not yet been used for nutrient substances such as potash salts, urea, etc.; but experiments along these lines are contemplated. These substances, having comparatively small molecules, are likely to travel rather more freely than dyes or even iron salts. Their flow may, therefore, have to be restricted somewhat by making the cut, not through the leaf-stalk, but through the blade of the leaf.

Summary.

When liquid is absorbed by a leafy shoot through the stump of a leaf-stalk, left after the rest of the leaf has been removed, it permeates parts of most of the neighbouring leaves in a regular manner. In certain leaves the blade on one side of the main vein is permeated, the corresponding area on the other side of the main vein being unaffected. If solutions of suitable mineral nutrient salts be injected, their effects may be watched by comparing these two areas. Rapid diagnosis of iron shortage in apple trees in the plantation has already been carried out by this method, which in all probability is applicable to other substances.

FIG. 1.

IRON SHORTAGE CHLOROSIS IN THE PLANTATION

A PROGRESS REPORT

By W. A. ROACH and B. F. G. LEVY

THE injurious effects on plants of an extreme shortage of available iron have been recognized for a long time. The trouble tends to occur on calcareous soils, such as those in the Swanley-Eynsford district of Kent, and results in the loss of all or part of the green colouring matter of the leaf ; consequently it is known as lime-induced chlorosis. There also appears to be a less severe form of the same trouble, and it has recently been recognized in the Research Station plantations; reasons will be given later for suspecting that it occurs much more widely than the more severe form. The only symptom of the less severe form so far noticed is the light slightly unhealthy colour of the leaves, which is indistinguishable from that resulting from a slight shortage of nitrogen. The degree of importance of this trouble, which will be referred to as incipient chlorosis, cannot at present be assessed ; but a decrease in the amount of the all-important green colouring matter of the leaves can hardly fail to result in some measure of reduced vigour in the trees. A short account of the preliminary experiments so far carried out on the general problem of chlorosis will, therefore, be given.

SEVERE CHLOROSIS IN THE SWANLEY DISTRICT.

Experiments already reported (3) carried out on a peach tree showed how serious severe chlorosis can be. This tree presented a striking yellow appearance when seen from a distance ; the healthiest leaves were of an unhealthy light green colour, especially along the edge and between the veins, and the worst leaves were almost completely yellow, the small amount of green colour being along the veins. This tendency of the veins and parts near them to remain green when the rest of the leaf is yellow or yellowish green distinguishes this type of trouble from that caused by a shortage of nitrogen ; but closely similar, or identical, symptoms result from a shortage of copper, magnesium, manganese and zinc, all of which have proved of economic importance overseas ; manganese shortage has been proved in a few places in this country and preliminary experiments carried out in Cornwall by Messrs. Abbis and Beckley in co-operation with us suggest that there is a shortage of magnesium there; it cannot be assumed, therefore, that symptoms such as those just described are necessarily the result of iron shortage ; but definite experiments must be done. In the case of this peach tree a small scale injection of an iron salt through the cut end of a current year's shoot was followed in a week by the development of a normal green colour in the two and a half leaves nearest to the cut, proving that iron was the element actually required. The whole tree was injected and a week later the leaves had become of a practically normal green colour and the peachlets, which previously had remained the size of peas for five weeks, began to grow. These eventually grew into a crop of good quality and of nearly normal size. There is little doubt, therefore, that the original unhealthy condition, which was so serious as to make the tree worthless, was due to iron shortage.

The peach tree is growing in a greenhouse belonging to the Swanley Horticultural College. Many apple, pear and plum trees, growing in the open near by, are seriously affected by what is almost certainly the same trouble. Experiments which are being carried out on these trees will be mentioned later.

In a mixed apple and pear plantation belonging to Mr. Sidney Lee of Crockenhill, Swanley, trees show all stages of the trouble, ranging from ones which produce good crops of high quality fruit to others which have become practically useless. This trouble has also been proved by experimental injections to be due to iron shortage.

Chlorosis in the Sittingbourne District.

In certain areas of Mr. L. Doubleday's plantations the foliage of Roundel Heart cherry trees and some varieties of apple and pear show symptoms similar to those already described. The foliage of the cherry trees becomes progressively yellower and the crop becomes less year after year ; eight acres of trees which should be in full bearing have already been grubbed. A shortage of iron has been proved by injection experiments on these trees. They grow in a typical deep brick earth over grass which is stocked with sheep. Trees of similar appearance may be seen elsewhere in this district.

Evidence of Iron Shortage at Malling.

When observing the trees already mentioned suffering from true chlorosis and others of similar appearance elsewhere, it has often been noticed that trees with some branches affected by the trouble and others healthy, have some leaves which are not mottled with yellow or light green as in typical chlorosis, yet are of a lighter green colour than the best ones on the healthy branches. Such leaves are often lacking in lustre or "finish" and appear to be lacking in health. It was suspected that the light unhealthy green of these leaves was an early symptom of iron shortage and this suspicion was strengthened by the results of an experiment reported elsewhere in this Annual Report (p. 146). In this experiment apple trees were slowly "starved" of iron. As a result the leaf at the base of the shoot, being the first to unfold, had a reserve of iron to call on ; when the next leaf unfolded there was less iron available, and so on, each leaf having less iron to draw on than the one preceding it ; consequently the leaves on a single shoot showed graded symptoms of iron deficiency, the intensity increasing the farther the leaf was up the shoot. The leaf at the base of the shoot was of a normal healthy green colour, the next one was of a slightly lighter green, the next one lighter still, and so on until a leaf was reached which had a mottled appearance due to its having bands of light, or yellowish green round its edge and between its veins. This leaf and succeeding ones showed the symptoms already known to be typical of iron shortage chlorosis, the symptoms becoming more and more severe towards the top of the shoot, the top leaves being yellow and entirely devoid of green. An iron salt dissolved in water was injected into a small area on one side of the main vein of a leaf and between two secondary veins so that the effect could be studied by comparing this area with that on the other side of the veins (see p. 142). In this experiment, carried out on leaves showing severe symptoms, normal green colour was produced ; and in the leaves near the base of the shoot, which were of a light green colour that was uniform over their whole area, the injection was followed in a few days by an increase in the depth of green, until the injected areas were as dark green as the healthy leaf at the base of the shoot. These facts leave little doubt, therefore, that a shortage of iron, not severe enough to result in a mottling or a yellowing of the leaves (true chlorosis), causes the leaves to be of a light green colour (incipient chlorosis).

A case of severe chlorosis in a pear tree grown in ordinary soil in a pot has been reported (4) and a number of other trees grown in this way have shown the same symptoms; it seemed possible, therefore, that trees growing in the same soil in the plantation might suffer from a mild form of the same trouble. Early Victoria apple trees do show such symptoms and the injection of trees of this variety in Kiln Field on this Station proved that the symptoms were due to iron shortage. These injections were carried out at the end of July by the leaf-stalk method, which is described on p. 150. This rapid method was used at the same time to test trees of other varieties. Rev. Wilkes on plot 33 had foliage which, though yellowish, did not resemble at all closely typical chlorotic foliage. The injected areas of the leaves of this variety took on a much more normal green colour, proving that it is suffering from iron shortage, but it cannot yet be said whether this is the only trouble. Trees of Lane's Prince Albert on plot 10 and of Moss Orchard, Bridget and Underleaf on plot 33 had foliage of a somewhat unhealthy-looking green colour but without any signs of yellowing or of true mottling. All these varieties responded to injection in the same way. The injected areas of the leaves took on a much darker healthier green appearance than the uninjected parts. Thus, six varieties of apples, selected more or less at random at the two ends and in the middle of the Research Station plantations, were all apparently benefited by an injection of iron salts. This fact seems to justify a more careful survey of the position. We hope to carry this out next season, not only in the Research Station plantations but also elsewhere.

The Cause of Iron Shortage Chlorosis.

Our knowledge as to the cause of iron shortage chlorosis is still somewhat uncertain. It may be caused by an actual shortage of iron in the soil itself; usually there is more than enough iron in the soil but the plant is unable to use it. In extreme cases the plant is unable to absorb a sufficient amount; more often the plant absorbs the iron but is unable to use it because it is deposited in an insoluble form (usually as phosphate) before it reaches the blade of the leaf. This tends to happen when the tree is growing in a soil containing plenty of chalk or limestone, particularly if there is much phosphate present. It is useless to add iron or iron salts to such a soil because the iron will become precipitated before it reaches the leaves. The presence of rotting organic matter, such as farmyard manure, tends to keep iron in the available form. Faulty absorption of iron might, therefore, be expected now that less dung is used than formerly. These considerations suggest possible methods for curing the trouble.

The Cure of Iron Shortage Chlorosis.

Application of iron salts to the soil. As already stated this method is not often successful; but, because of its simplicity, it seemed worth trying.

At Sittingbourne, iron (ferrous) sulphate was applied in November, 1935, to the area of soil such as that shaded in Fig. 1, half of it being treated at the rate of 1 cwt. per acre and half at 5 cwt. per acre. In this way a quarter of the tree would be treated with a dressing of 1 cwt. per acre, a quarter at 5 cwt. and half would be left untreated.

As will be explained later (p. 158), this method reveals small differences which would not be noticed by the more usual method of treating a number of trees and leaving a similar number untreated. Even this sensitive method failed to reveal a definite effect of the application.

Ferric citrate was applied at the same time to half the area of soil under another tree, i.e. to an area such as that shaded in Fig. 1, at the rate of $\frac{1}{4}$ cwt. per acre, this being

the highest rate of application which it was considered would be economically possible in view of the greater price of this substance. On 29.9.36 when light conditions were particularly good, an effect of the application was just visible ; but it was too small to make the treatment of any practical value.

This same substance was also applied at the same rate and at about the same time to the soil under half an apple tree at Swanley. No effect of the treatment was apparent.

These results do not encourage the hope that the application of iron salts to the soil will cure chlorosis on these two types of soil. Applications of iron salts in trenches or through holes drilled in the soil have not been tried.

Injection of iron salts.

1. *Solid injection.* This method consists in placing powdered iron salts into holes drilled in the trunk or main branches. It has been described in detail by Bennet (1) ; it has been used successfully for some years in America in commercial plantations and there is little doubt as to its efficacy ; but it has the disadvantage that considerable mechanical damage is done to the tree in drilling the holes. The effect lasts for three or four years, after which the treatment must be repeated. Its use may be justified only in the absence of a better alternative.

A modification of this method designed to lessen the amount of mechanical damage was tried on one tree at the Swanley Horticultural College and it was partially successful.

2. *Liquid injection.* The liquid injection method has the advantage over the last one in that much less mechanical damage is done. The liquid enters the tree through two $\frac{1}{4}$ inch (or smaller) holes, drilled nearly half-way through the main stem. This method has been used successfully on the peach tree already mentioned and on a few other trees, but, like the last one, its use will only be justified in the absence of a better one. It is hoped to test these two methods more fully next season.

Driving iron nails into the trunk or branches. This method has been used with some success (2). At Sittingbourne 1 inch iron oval nails were driven into three branches of a cherry tree, $\frac{1}{2}$ inch, 1 inch and 2 inches apart respectively. All three branches showed an effect ; the first one bore leaves which were of an almost completely healthy green, in marked contrast with the yellow foliage of untreated branches. This method will be given a more extended trial.

In all the methods so far considered iron has been added. In the ones which follow the aim is to render the iron already present in the soil more readily available to the tree. Their efficacy seems to depend on the ability of certain plant and animal materials to keep iron in a soluble condition in which the tree can absorb and use it.

Grassing down. This method has been applied successfully following experiments carried out by Wallace (5). It is not always convenient to grass down and the condition of the cherry trees growing over grass at Sittingbourne proves that grassing down alone is not always successful.

Breaking down the turf. The beneficial effect on cherry trees of periodical breaking down the turf so that it may rot is well known. One effect of this operation is to liberate some of the organic matter previously locked up in the turf and allow it to reach the lower layers of the soil, where it may be available for use by the cherry roots. In a grazed orchard parts of the grass eaten and parts which die from other causes are constantly returned to the soil in rotting condition ; but the grass roots have a chance of making use of them before they can reach the deeper cherry roots. When the turf is broken down a much bigger proportion of the grass is rotted down and, the competing

grass roots having been killed, the cherry roots should stand a much better chance of being able to make use of the rotting organic matter. In the hope that one effect of such rotting organic matter might be to supply iron to the cherry roots in a useful form, the effect of turning over the turf with a fork was tested. This again was done by the half-tree method (see Fig. 1); that is, the turf under one-half of the tree was turned, leaving the other half untreated for comparison. The following summer the leaves on the treated half of the tree were definitely greener than those on the untreated half, but they were not fully restored to health. The same was true of at least four " quarter-trees " in which some other treatment was combined with the present one, the turning in of the turf combined with the other treatment in each case being better than the other treatment alone. It is proposed to carry out an experiment on a larger scale to test how far the breaking down of the turf will bring about a cure of the trees.

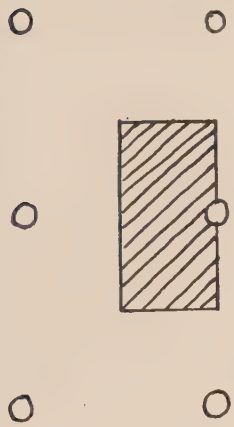

FIG. 1.

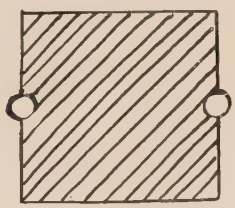

FIG. 2.

The circles represent tree trunks and the shaded part the treated area.

The application of organic matter to the soil. A dressing of well-rotted farmyard manure at the rate of about 40 tons per acre spread on the turf had a definite beneficial effect. The intensity of the green colour appeared to be about half the normal, whereas the untreated half was certainly less than a quarter of the normal. The same amount of farmyard manure, after being spread under half of another tree, was turned under with the turf. The effect of this combined treatment was not much greater than that of turning the turf under alone, or than that of the manure spread on the turf; but the comparisons were not as accurate as the ones so far mentioned because different trees were being compared instead of the two halves of the same tree.

Other sources of organic matter were also tried:

Dried blood (5 cwt. per acre) applied to the turf had no perceptible effect.

Peat. " Chicken " peat from Yorkshire spread on the turf at the rate of 4 tons per acre brought about a slight improvement in colour.

Attempts were also made to render the organic matter in the peat more soluble and so possibly better able to convert the iron in the soil into a soluble form which the trees could use. In the first of these the moistened peat was mixed with dried blood and kept in a heap for four weeks to " rot ".

Four other lots of peat were treated with caustic potash, ammonia and two samples of slaked lime respectively and kept in a heap for four weeks. None of these treatments

made the peat appreciably more effective in restoring the green colour to the cherry trees.

Similar experiments on organic manures were carried out at Swanley on trees growing in a clean-cultivated garden. The trees were growing in a row. Each treatment was applied to the square of soil " between " two tree trunks (see Fig. 2) ; so that the half of each of two trees was treated and consequently two comparisons could be made for each treatment between a treated half-tree and an untreated one. The treatments were :

Well rotted farmyard manure (about 50 tons per acre). There was a barely detectable effect on one half-tree and no apparent effect on the other.

Sorbex peat (5 tons per acre), forked into the ground. One treated half-tree was a healthier green than the untreated one ; but the other one was apparently unaffected.

Sorbex peat rotted with chicken manure. There was no apparent effect on a pear tree which was not badly chlorotic ; there was a small but appreciable effect on a more chlorotic apple tree.

Peat treated with caustic potash. There was more growth on the treated halves of both trees but they were equally chlorotic.

Peat treated with ammonia. There was more growth on the treated half of an apple tree, but both halves were equally chlorotic. There was no apparent effect on a pear tree.

Peat treated with slaked lime. There was no apparent effect.

The Use of the Half-tree Method for Manurial and other Experiments.

As already stated, most of these experiments were carried out by the half-tree method (see Figs. 1 and 2), in which the ground under one half of the tree is treated, the other half being left untreated for comparison. The treated and untreated halves are on either side of a straight line passing through the middle of the trunk. Two facts have to be taken into account in looking for the effect in the top. First, the trunk is sometimes twisted. With a little experience this twist can usually be recognized at sight and allowance can be made in looking for the division between affected and unaffected branches. Second, although branches usually are nourished by roots immediately " below " them (allowance of course being made for twist), some branches are connected with roots on both sides of the trunk. Such branches can be recognized by studying the spacing of the branches around the main crutch. Should this method continue to be as useful as in the above experiments these principles will be described in detail later. In these experiments the method was more than justified. By its use small effects of treatment were seen with reasonable certainty which, as far as we know, could not have been detected by any other field method. The main reasons for this ease in detecting small differences due to treatment are (1) that the two halves of a tree usually resemble each other more closely than two neighbouring trees ; and (2) the two halves of a tree are closer to each other, and consequently more easily compared, than two separate trees.

Conclusion.

The experiments just described are still in the preliminary stage. None of the soil treatments or applications tried offers any definite hope of a complete cure of the trouble in one year but they do suggest the possibility of a complete cure being obtained gradually in the course of a few years.

Driving nails into the tree trunk offers some hope of a rather more rapid cure. The trouble may be remedied by injection in one season; but injection, if relied on alone, must be repeated every three or four years.

Unless the soil treatments can be made more rapidly effective it may be necessary to bring about a temporary cure immediately by injection, or possibly by nailing, and a more permanent one more gradually by soil cultural means. Experiments are being continued along these lines.

Experiments are contemplated to determine how far the incipient stage of iron shortage chlorosis is important itself and how far it may be looked on as a symptom giving warning of future trouble.

Acknowledgments.

Much help received in carrying out these experiments is gratefully acknowledged: to Dr. Kate Barratt for placing valuable experimental material at our disposal, to Dr. K. M. Smith and Miss G. B. Brydon for assistance given in the course of the experiments and to Messrs. L. and G. Doubleday for placing the resources of their farm so freely at our disposal.

Summary.

1. A description is given of a chlorosis of the iron shortage type which seems to be associated with faulty orchard performance.

2. What was proved by injection methods to be an incipient stage of the same trouble is characterized by a light green colour of the foliage indistinguishable at sight from that associated with nitrogen shortage.

3. This incipient iron shortage chlorosis appears to be more widespread than the more severe form.

4. Preliminary experiments on the cure of chlorosis are described.

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THE INJECTION OF INDIVIDUAL BRANCHES OF A TREE INDEPENDENTLY OF EACH OTHER

By W. A. ROACH

Introduction.

When experiments are carried out on fruit trees in the plantation it is often difficult to decide how much of the observed difference between treated and untreated trees is the result of the experiment and how much is due merely to the natural variation from tree to tree seen in all plantations. This difficulty is usually overcome by selecting for treatment and for comparison trees in sufficiently large numbers and distributed so widely over the plantation that this variation from tree to tree is " evened up ", and a rigid statistical analysis of the results is possible. But there are many problems to which such statistically planned experiments are inapplicable. Such problems are often presented by commercial plantations, for example, the determination of mineral deficiencies. On these it is rarely possible, for practical or economic reasons, to carry out the detailed and costly operations involved in such experiments. But there are obvious advantages in carrying out the experiments actually in the plantations to which the results will eventually be applied. There is room, therefore, for an additional method which can be used in the commercial plantation.

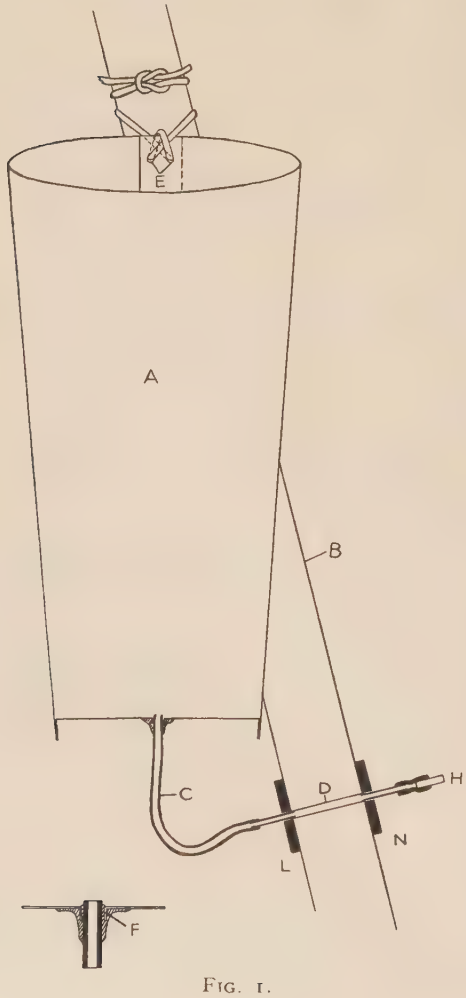

Fig. 1.

In the injection method to be described in this note the various treatments, instead of being tested on groups of trees, are tested on individual branches of single trees. In many commercial plantations trees differ widely from each other ; this is particularly true of plantations of trees suffering from mineral deficiency ; but even in such plantations a number of branches, sufficiently uniform for experimental purposes, may usually be selected on a single tree. The number of such comparable branches on twenty-year-old trees may reach twenty or even more. Comparisons between treatments may, therefore, be duplicated, or even repeated more often, on a single tree. Further repetition on similar trees makes for greater certainty in the deductions eventually drawn from the experiment ; and repetitions on

dissimilar trees, for example, poor and extremely poor ones, will reveal whether the condition of the latter is but an extreme manifestation of the one trouble, or whether different trees in the same plantation suffer from different troubles which call for detailed treatment.

General Description of Method.

A solution of the substance to be tested is held in a reservoir A (Fig. 1) attached to the branch B and the solution flows thence through rubber tubing C under a few inches head of pressure into a hole D drilled diametrically through the branch.

Distribution and Localization of Injected Liquid.

As is well known, the pull of the leaves on the water in the woody tissues of the tree keeps practically all these tissues in a state of suction ; consequently, the injected liquid rushes up the conducting channels actually severed by the hole and so into the leaves. These facts and the ones which follow are readily demonstrated by injecting a suitable dye solution (see p. 164) and later removing the bark from the stem to lay bare the wood. The rate of travel upwards varies but is generally about $\frac{1}{2}$ inch per minute. It travels circumferentially around each annual ring of the wood at about $\frac{1}{20}$ inch per minute until the whole circumference of the branch at the level of the hole is permeated. Soon after the injection is started, therefore, every leaf above the hole draws on the liquid and, during the progress of the injection, the entire flow of sap is replaced by injected liquid.

The injected liquid also moves down the branch at a rate which at first is about equal to that of the upward movement. When dye is injected and the wood laid bare two bands of colour the width of the hole start one from each end of it and travel down along the grain of the wood, i.e. it follows the strands of which the wood consists. As the dye travels around the circumference of the branch these bands broaden until they meet and the whole circumference is permeated. When the first side-branch A (Fig. 2) below the hole is reached the colour is seen to follow the strands and flow on either side of it, leaving uncoloured the strands (drawn heavily in the figure) immediately below the side-branch and in direct connection with it. This is shown in Fig. 2 which is drawn looking down on the stump A of the side-branch which has been cut off just above the swelling where it joins the main stem. But the leaves borne by this side-branch tend to keep the strands (drawn heavily) in direct connection with it in a state of full suction, whereas the suction in the permeated strands (drawn lightly) has been reduced by the inflow of injected liquid ; coloured liquid, therefore, flows from the first strands into the second and a band of colour is seen to ascend the side-branch on its side nearest to the main branch. This band broadens and, if the diameter of the side-branch is not more than one-quarter that of the main branch, it will be completely permeated. The same happens when each succeeding side-branch is reached, so that when the second side-branch B (Fig. 3) is passed, the originally undivided cylinder of injected strands is now divided

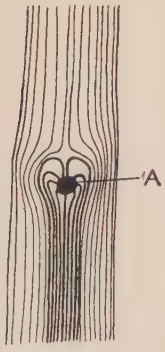

Fig. 2.

Fig. 3.

into two ; when the third is reached into three ; when the tenth is reached into ten parts, and so on. Fig. 3 was reproduced from a photograph of a short length of a spur-pruned branch in which the strands in direct connection with side-branches were injected and coloured. The injected liquid, therefore, flows along strands (left white in Fig. 3) which are divided as each side-branch is reached. The flow of the injected liquid is impeded by the high resistance offered by the walls of the fine tubes along which it travels and it is being drawn on by more and more absorbing side-branches as the main branch is descended. Further, the normal sap will flow upwards as soon as a certain suction is re-established. It is obvious, therefore, that a point must soon be reached beyond which the injected liquid is unable to travel. As might be expected, this point is reached more quickly in a spur-pruned main branch, which has on it many side-branches, than in a main branch which has few, or no, side-branches.

Apparatus.

A milk carton (A, Fig. 1) made of wax-impregnated paper is perhaps the best kind of container for the liquid, both because it is light and because its conical shape allows of many being " nested " together in small space when not in use. Two holes E are punched in the part where the paper is double near the top and strengthened with metal eyelets introduced with the usual machine. String thick enough to fill these holes, as nearly as possible, is threaded through them as shown in the figure. This kind of suspension will withstand all weather conditions except a gale. A hole is made in the bottom of the carton with a long-handled reamer from the inside. In this way a small external collar F is made. The end of a suitable length of rubber tubing,* 2 mm. in external diameter, is moistened on the outside with rubber solution, care being taken to let none get into the hole, and inserted in the hole until it is flush with the bottom of the carton. Rubber solution is run over the outside of the tube and of the collar, and a little on the base of the carton to form a sheath, and the carton is left upside down until the rubber solution is dry, when the rubber tubing is found to be fixed firmly into the carton.

Two pads, each measuring 4 cm. × 2.5 cm. (1½ in. × 1 in.) for a large branch or smaller for a smaller branch, are cut from rubber sheeting about 3 mm. (⅛ in.) thick. A small hole is made in the centre of each with a leather punch and into each is inserted the end of a piece of glass, or stainless steel, tubing, 1½ cm. (⅝ in.) long and 2 mm. in diameter, so that it protrudes about 1 mm. The small cap H is made by plugging one end of a short piece of rubber tubing with a piece of glass rod or a piece cut from a wire nail. A binding strip measuring about 10 in. × ¾ in. is cut from a discarded bicycle inner tube. For each injection in progress at a given time the above set of apparatus is necessary ; but all the items, with the possible exception of the binding strip, may be used many times.

In addition, each worker or group of workers requires a set of tools for making holes of the required size or sizes through the green wood. These consist of :

1. A set of new metal drills, 1/16 in., ⅛ in., 3/16 in., ¼ in.† in diameter. The larger sizes are best mounted by cutting the blade from a ratchet screwdriver and fixing the drill in its place, as shown in Fig. 4. Smaller sizes are mounted in wooden handles as shown in Fig. 5. These may be roughened or a piece of rubber tubing C pulled over them to improve the grip.

2. A set of steel cork borers, each just large enough to slip freely over the corresponding drill.

* R.S.C. (red steam cured) valve tubing obtainable from Messrs. Dunlop Rubber Co., Cambridge Street, Manchester at 12s. 8d. per lb. of approximately 90 yards.

† Or of Irwin type as described on p. 177.

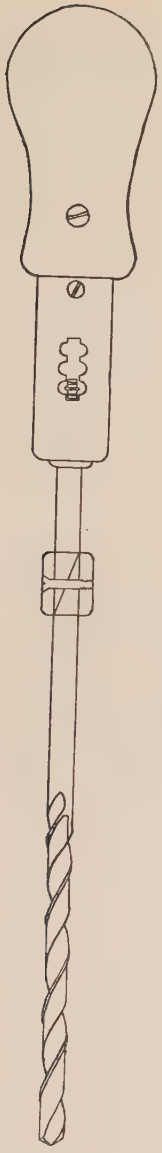

Fig 4.*

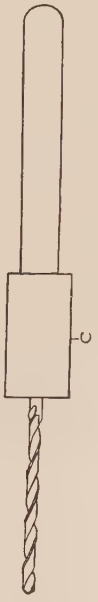

Fig. 5.*

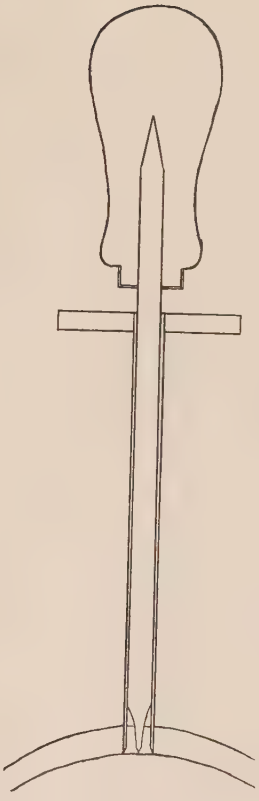

Fig. 6.*

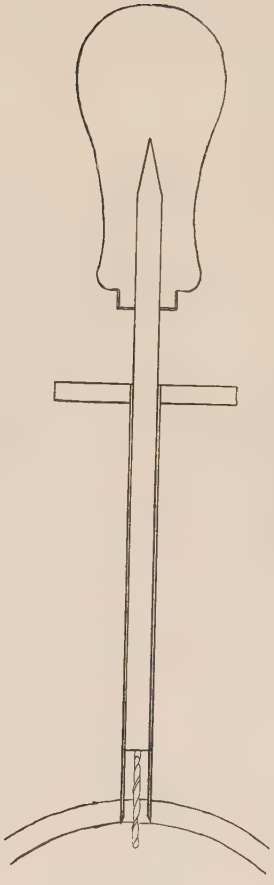

Fig. 7.*

3. A set of metal rods sharpened into a chisel at one end and fitted into a wooden handle at the other (see Fig. 6).

4. A set of metal rods each of which fits inside a cork borer. Each rod has soldered concentrically into its one end a drill of about one-quarter its diameter and the other end is fitted with a wooden handle (see Fig. 7).

5. A pad of pure or nearly pure rubber of about the following dimensions: $2 \times 2 \times \frac{1}{2}$ in.

* These drawings were done by Mr. R. Cornford who also made the instruments and helped in their design.

PROCEDURE.

The procedure will be described in detail because experience has shown that slight departures from the recommended method may make an operation, which should be simple and satisfactory, appear difficult and render it ineffective.

Position of hole. The general principles underlying the injection of a branch so that it alone is permeated and none of the liquid travels into any other branch have already been given. When the branch is well furnished with small side-branches, such as fruiting spurs on a spur-pruned tree, the injected liquid does not travel more than one-third as far downwards towards the main stem as it does upwards, in which direction we have already seen it reaches the tip. In such material, therefore, the hole is bored at a point one-quarter the distance from the desired lower limit of penetration upwards to the branch tip. This is the only general rule which can be given. When the base of a branch is not well furnished with side-branches the hole must be made higher up. In the two papers which follow will be described the application of the method to the branches of spur-pruned trees and to branches poorly furnished with side-branches, or with no side-branches at all below the injection hole. These examples will give some guidance in the selection of branches for injection and in the placing of the injection holes ; but all such experiments should be preceded by ones carried out with dyes until it is possible to predict in the particular material under experiment the extent of downward penetration resulting from injection at any given point. The following dyes have been found most useful for this purpose : light green, patent blue and acid fuchsin (red) ; at first 0·2 per cent. solutions should be used ; but after a little experience 0·1 per cent. solutions may be found quite satisfactory. If this weaker solution is used and if the branch be not allowed to absorb it for more than twenty-four hours usually it suffers no permanent harm. The dye collects round the margins and between the veins of the leaves in the course of a few days ; these parts shrivel and later fall off, and in severe cases the whole leaf falls. More severe damage results from the use of the more concentrated solution but even this rarely does permanent damage. These remarks apply to the dyes mentioned above and not to others such as eosine which in the past have been used for plant injection and which are much more toxic. When in doubt as to whether a particular leaf is permeated or not the question may be settled by scraping the underside of the leaf-stalk, near its junction with the shoot, to lay bare the vascular tissues, which become noticeably coloured before the colour is detectable in the blade.

Drilling the hole. The following three points connected with the drilling of the hole are of importance :

1. In order to avoid unduly weakening the branch structurally and to allow the ends of the hole to heal up quickly the hole should be as small as possible.

2. The cambium at each end of the hole should be damaged as little as possible so that healing should be rapid. It is better to remove a little extra bark and leave a neat wound than to leave a ragged one, which heals slowly.

3. The hole through the wood should be perfectly " clean ". The use of a sharp new drill without undue pressure results in the wood removed coming away in small bits instead of becoming jammed together and being rubbed against the wall of the hole and, as a result, closing up the cut ends of the conducting tissues of the wood.

Having decided on the approximate position of the hole, as already described, the actual position should be the middle of the nearest piece of the stem which is free from side-branches and other obstructions for a few inches. The hole must be made above the position tentatively decided on if necessary to avoid any risk of the liquid travelling into other branches.

The area within a distance of 1 cm. ($\frac{1}{2}$ in.) or more from each end of the hole should be smooth and free from excessive lichen growth, and if not it should be made so with a scraper or cloth without damaging the bark.

The diameter of the branch at this point is measured with calipers, a drill of suitable diameter is selected, and on it is marked a depth about four-fifths of the diameter of this branch. The simplest way of doing this is to twist a pipe cleaner round the drill at the right point.

One end of the hole is marked out by pressing the cork borer, of size next larger than the drill, through the bark and just into the wood. The cork borer is held in position while the ring of bark is removed by pressing into it the chisel end of the rod shown in Fig. 6 and rotating it. The cork borer is removed temporarily, if necessary, to clean out the bits of bark.

The rod ending in a drill (Fig. 7) is now inserted into the cork borer and a hole drilled in the wood to a depth of say $\frac{1}{2}$ cm. ($\frac{1}{5}$ in.). The injection hole is now drilled, the shallow hole just described being used as a starting hole. This facilitates the injection hole being drilled concentrically with the slightly larger hole in the bark, so as to allow a space all round the hole between the drill and the bark to prevent the drill getting in contact with the bark, which would tend to make it sticky and cause the bits of wood to stick to it. If it is kept quite clean the bits of wood come away freely and do not get pressed against the side of the hole, closing up the mouth of the conducting cells and tending to lift the bark from the wood near the mouth of the hole.

The injection hole is now bored to the mark on the drill, i.e. so that it does not quite reach the bark on the other side of the branch. A small concentric hole is drilled in continuation of this hole, through the remaining wood and bark with the rod which ends in a drill (Fig. 7), undue damage to the bark being avoided by holding the pad of rubber firmly against it. The drill is removed, the cork borer is slipped over the rod, and the drill is inserted to its full depth in the other end of the hole. The cork borer is pressed through the bark to mark out this end of the hole. With the cork borer still in position the ring of bark is removed, as before, and the drilling of the hole full size is completed from the second end.

Binding tube-pads in position. One end (K, Fig. 8) of the rubber strip is placed $\frac{1}{2}$ in. to 1 in. (according to the size of branch) below the hole D ; the branch is held firmly in the left hand and the end of the strip is held between the thumb and the branch. A few inches of the strip are stretched with the right hand to two or three times the original length, wrapped round the stem and held under the forefinger on the far side of the branch ; the right-hand grip is changed, and another length is stretched and wrapped round the branch and over the end K to hold it firmly. The left hand may now be removed, the branch being steadied, if necessary, by placing the little and fourth fingers of the right hand against it, the remote, or left-hand tube-pad L (Figs. 1 and 8) is placed so that the shorter protruding end of the tube is in the mouth of the hole in the branch, the stretched strip is wrapped over the pad on one side of the tube, the second pad is put in position in a similar manner and the binding is completed as shown in the figure, the last turn being wrapped over the forefinger, with which a loop is pulled under it. This loop is a great convenience in taking the apparatus down.

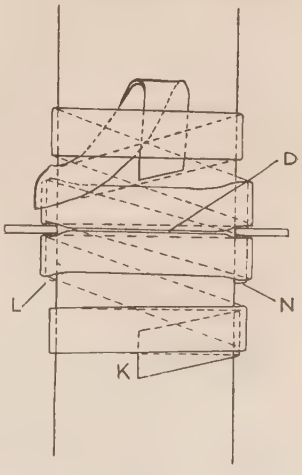

Fig. 8.

The binding as described above if carried out efficiently is sufficient to make a liquid-tight joint in the great majority of cases, but occasionally, for example, when the branch is of an inconvenient shape, a few more turns are necessary. It is sometimes an advantage to bind above one tube and below the next and so cross the bandage so as to concentrate the pressure on the parts of the pads along the lines immediately between the tubes, as this position tends to be under less tension than elsewhere.

Pouring in liquid, etc. With the tubing C hanging vertically the liquid is poured quickly into the container. The amount of liquid lost before the end of the tube is pinched is negligible. The end is connected to the one short tube and as soon as the liquid flows out from the other tube the small cap H may be placed over it to stop the flow (see Fig. 1.)

Should the liquid not flow from the second tube-pad N (Fig. 1) in all probability one of the tube-pads has been dragged in the binding operation until the end of the tube is embedded in the bark and so closed ; and the binding of the tube-pads should be repeated ; but if the above instructions are followed, and if an even tension be applied to the strip, this difficulty should practically never be experienced.

When a series of injections is being carried out the operation should occupy less than five minutes per branch on the average.

Conclusion.

The method described in this note has been tested with dye solutions and with solutions of nutrient mineral salts at concentrations just high enough to produce slight damage to the leaves. The course of these solutions could then be traced rapidly by the colour of the dye in the leaves and in the wood, and by the damage shown by the leaves. How far nutrients and other substances in harmless concentrations follow the same laws, and how far such substances and the effects which they produce are also restricted to the injected branches can only be ascertained by experiment ; and some years are likely to elapse before the field of utility and the degree of reliability of this method can be defined. The two following papers describe the application of the method to two somewhat extreme types of trees, the first to spur-pruned trees which are easy to work with and the second to trees which have been regulated but have not been spur-pruned ; these latter trees have long pieces of branch without any side-branches ; consequently the hole must be made higher up the branch and more judgment is necessary in placing it. These two papers suggest that the effects of injection as well as the actual substances injected are localized in the injected branches for at least the current season.

If nothing be done to the hole it heals over during the current season, but it may be closed with a piece of grafting or insulating tape as a precautionary measure.

Summary.

1. Selected branches of a single tree may be injected independently each with a different solution.

2. The injected liquid is absorbed through a hole bored diametrically through the branch at a point three-quarters the distance from the branch-tip to the limit within which it is desired to confine the permeation.

3. The liquid held in a reservoir is led through rubber tubing to the hole, a water-tight joint being made between them.

4. The branches are not damaged appreciably by the operation if it is carried out properly.

THE INJECTION OF INDIVIDUAL BRANCHES OF A SPUR-PRUNED PEAR TREE

A PROGRESS REPORT

By D. N. SRIVASTAVA and W. A. ROACH.

Introduction.

The previous note described a method for injecting separate branches of a tree each with its own liquid without any immediate effect on the rest of the tree. This method was worked out and tested mainly on apple trees and using solutions of dyes or of mineral nutrient salts in slightly toxic concentrations. The present note describes a preliminary attempt to determine how far the method can be applied to a physiological problem such as the effect of nutrition on " June drop " in spur-pruned pear trees. The experiments so far carried out had not determined how long or to what extent the injected substances remained in their own branches nor to what extent the physiological effects of the substances were confined to the injected branches. It was to throw light on questions such as these that these preliminary experiments were carried out and also to gather the general experience necessary for designing a definite experiment.

Experimental Material.

The experiments were carried out on four pear trees, variety Beurre Hardy, which had been trained by the open-centre method and which had been leader-tipped and spur-pruned. This variety shows a strong tendency to concentrate its growth in one main central " leader " branch. Most of the branches were making little or no extension growth but what growth there was, was concentrated in branches which arose nearer the centre of the main crutch than the rest. Such branches were, therefore, avoided in selecting the ones for experiment. From each tree were selected ten branches of uniform length and thickness, and which in the previous season had made little or no extension growth. The injection points are indicated by white labels in Fig. 1 which is a photograph of four branches.

Experimental Procedure.

The branches were injected during the first week of June, 1936, when a few leaves had fully expanded, the method described in the previous note being used. The branches were treated in groups of five as follows :

A. Water.
B. 0·5% Urea $CO(NH_2)_2$.
C. 0·5% Urea $CO(NH_2)_2$.
   0·5% potassium phosphate K_2HPO_4.
D. Water.
E. Untreated.

There were two replicates of each of these treatments on each of the four trees ; thus there were eight replicates of each treatment in all. Two trees were injected during the afternoon of 4/6/36 and the remaining two the following morning. Absorption was slow, doubtless as a result of the wet weather. All the nutrient injections were stopped on 7/6/36, by which time the four branches on the tree injected first were more heavily

damaged than was intended, especially the ones injected with potassium phosphate in addition to urea. The remainder showed slight leaf damage, which in the absence of a better system of dosage, was taken as an indication that the trees had absorbed enough. The water injections were allowed to proceed for one week.

TABLE I.

VOLUMES OF INJECTED LIQUIDS ABSORBED (c.c.).

Tree.	Branch.	0·5% $CO(NH_2)_2$		0·5% $CO(NH_2)_2$ + 0·5% K_2HPO_4		Water.		
		5-7/6/36	6-7/6/36	5-7/6/36	6-7/6/36	5-7/6/36	6-7/6/36	Total for seven days.
18	1	1575		2760		less than 500		1630
	2	2910		2600		less than 500		1510
20	1	2120		2675		less than 500		1230
	2	2410		1950		approx. 1000		2480
22	1		2690		1600		approx. 500	2460
	2		1830		1175		less than 500	1640
24	1		2550		1100		approx. 1000	2270
	2		1620		1920		less than 1000	2130
18	1					less than 500		1575
	2					less than 500		1870
20	1					less than 500		1700
	2					approx. 500		2050
22	1						less than 500	1920
	2						approx. 500	1480
24	1						approx. 1000	2275
	2						approx. 500	1600
Totals for 8 branches		17700		15780		*a*. less than 5500 *b*. less than 4500		

VOLUMES OF INJECTED LIQUIDS ABSORBED.

The volumes of the various liquids absorbed by the branches are given in Table I. Both the urea solution and the one containing urea and potassium phosphate were absorbed three or four times as rapidly as distilled water alone. As may be seen in Table I the smallest volume of solution absorbed was larger than the largest volume of water absorbed. The chances against all sixteen of the one set of figures being by accident greater than all sixteen of the other set are 2^{31} to 1 or 2,000,000,000 to 1 ; there can be no doubt, therefore, that this difference in rate of absorption is a real one ; but this is the only result of the kind so far obtained here in the course of the work on tree injection.

Rumbold (2) obtained about twice as rapid absorption of alkali hydroxides and carbonates as of water using solutions of about $\frac{1}{5}$ the concentration used by us. She also found that rate of absorption increased with increasing concentration. Our rather more striking result is, therefore, in harmony with hers.

RESULTS.

The effects of the various treatments on fruit set and on shoot growth are set out in Table II. Whereas the number of fruits picked (see column 18/9/36) from 100 blossom trusses on the untreated and the two water-injected branches were 24,

TABLE II.

Above—NUMBER OF FRUITS FROM 100 BLOSSOM TRUSSES REMAINING ON TREE AT VARIOUS DATES ON VARIOUSLY TREATED BRANCHES.

Below—TOTAL SHOOT GROWTH MADE BY EACH BRANCH DURING 1936.

Tree No.		Water.			0·5% $CO(NH_2)_2$			0·5% $CO(NH_2)_2$ + 0·5% K_2HPO_4			Water.			Untreated.		
	Branches	22/6/36	23/7/36	18/9/36	22/6/36	23/7/36	18/9/36	22/6/36	23/7/36	18/9/36	22/6/36	23/7/36	18/9/36	22/6/36	23/7/36	18/9/36
18	I	36	29	29	40	35	32	15	9	4	38	27	21	44	34	34
	II	47	36	35	47	45	45	11	5	5	43	31	30	35	28	27
20	I	36	22	21	35	31	31	26	11	9	40	28	19	36	27	24
	II	35	23	22	32	24	6	35	23	10	47	38	23	45	34	34
22	I	47	35	31	25	19	7	25	12	3	51	36	28	41	30	19
	II	34	27	27	24	17	11	25	19	8	42	27	21	39	31	18
24	I	55	33	32	31	26	26	29	16	9	29	23	10	25	17	12
	II	35	28	28	30	24	10	32	10	9	42	33	22	38	27	25
Average		41	29	28	33	28	21	25	13	7	42	30	22	38	29	24
		Shoot growth (in cm.) made in 1936.														
18	I	0			69			740			0			66		
	II	25			252			1153			26			89		
20	I	0			49			559			0			0		
	II	33			299			561			190			0		
22	I	69			514			1047			29			77		
	II	0			204			260			29			0		
24	I	509			*—			765			123			140		
	II	194			245			1086			159			202		
Average		104			233			771			69			72		
Average for trees 18, 20, 21, 22		21			231			718			46			39		

* Branch was broken at the point of injection.

28 and 22 respectively, 21 were picked from the urea-injected branches and only 7 from the branches injected with potassium phosphate in addition to urea.

For reasons which will be given later the growth on the first three trees (Nos. 18, 20 and 22) will be considered first, and that on the fourth tree will be considered separately. In these first three trees growth on the untreated and on the water-injected branches was negligible ; there was a small but appreciable amount of growth on the urea-injected ones ; and there was a large amount of growth on the branches injected with potassium phosphate in addition to urea (see Figs. 1 and 2). Severe fruit thinning is known to result in increased vigour (1), consequently it cannot be said at present how much of the shoot growth on the injected branches is a direct nutritional effect and how much is a secondary effect due to the fruit thinning. These results suggest the necessity of (1) reducing the dosage in future experiments, (2) taking bud and fruit counts to make sure that a differential fruit thinning has not taken place or (3) removing all the fruit before injection if there be no objection to this course.

The fourth tree (No. 24) was at the bottom of a slope and it and the ones beyond it were markedly more vigorous than Nos. 22, 20, 18, and the remainder of the row. This increase in vigour did not affect all branches of the tree uniformly ; but a larger number of branches bore current year's shoots than in the less vigorous trees up the

slope, the remaining branches having little or no growth on them. As in the less vigorous trees, the branches which bore extension growths were those arising nearer to the centre of the tree than the rest, but because of the larger number of vigorous branches on the vigorous trees, a branch arising sufficiently near the centre to be vigorous on a vigorous tree, would bear no growths on a less vigorous tree. The one branch on the fourth tree (No. 24 in the row) which bore any appreciable number of extension growths in spite of being injected with water only, arose at a point nearer the centre of the tree, and so was more affected by the increase of vigour of the tree as a whole, than the remainder of the experimental branches. In view of these facts great care will have to be exercised in selecting branches for experiments from trees with a pronounced tendency to leader dominance.

Localization of the Effect of the Injection.

As was expected, in all the branches injected at points such as those indicated in Fig. 1, leaf damage below the injection point became less severe downwards and there was none within a few inches of the crutch joining the injected branch with the next ; hence no appreciable quantity of the injected liquid could have left any injected branch and travelled elsewhere in the tree. The growth response already referred to was equally localized. This may be seen in Fig. 2, in which many extension growths occur on the injected branch and not on the untreated one. The two join at a point just off the picture.

Conclusion.

The results of these preliminary experiments suggest certain precautions which must be observed when applying the branch injection method to physiological and other problems. The first concerns the choice of branches for experiment. These must arise in a similar manner at the main crutch ; above all must be avoided choosing some branches arising nearer the centre of the tree than the rest ; and especial care must be exercised in this respect when working on trees which show a strong tendency for one central branch or a few central branches to become stronger than the rest.

The second precaution concerns the effect on branch vigour of any fruit thinning resulting from injecting an overdose. If permissible the difficulty may be overcome by removing all the fruit ; if not, care must be exercised not to inject enough to cause a fruit drop and the fruits must be counted before and after injection to verify the fact that an overdose has not been injected.

If these precautions be observed in addition to those already enumerated in the previous paper it seems likely that the method will be of use for physiological and other problems.

Summary.

1. The results of preliminary experiments suggest that the physiological effects of injections made at suitable points in branches are confined to the branches.

2. They prove that the branches for experiment must be selected with great care so that all arise at closely similar positions on the main crutch, especially in trees which tend to produce one vigorous leader branch.

3. Unequal fruit drop on treated and untreated branches must be avoided.

References.

(1) Painter, A. C. Personal communication.

(2) Rumbold, C. "The injection of chemicals into chestnut trees." Am. J. Bot. 1920, **7**, 1-20.

FIG. 1.

Branches were (from *left to right*) : Untreated ; injected with water , with Urea+ Potassium Phosphate , with Urea alone.

FIG. 2.

Upper branch A untreated
Lower one B injected with 0·5% Urea $CO(NH_2)_2$ + 0·5% potassium phosphate K_2HPO_4.

THE INJECTION OF INDIVIDUAL BRANCHES OF A TREE WHICH HAS NOT BEEN SPUR-PRUNED

A PROGRESS REPORT

By P. K. SEN

THE experiments to be described in this note form part of an investigation of biennial bearing. Results having a direct bearing on the main problem are not expected yet but some have already been obtained which are of value in the development of the injection method used. This has been described by Dr. W. A. Roach on p. 160 (2).

Six twenty-two-year-old Bramley's Seedling apple trees in biennial bearing (3 in their " on " and 3 in their " off " year) were used for the experiment. Ten branches were selected on each tree as uniform as possible in size and in other respects ; and during the last week in June, 1936, one of the following ten solutions was injected into each branch :

1.	Sodium phosphate Na_2HPO_4 (0·5%)	P
2.	Potassium salts, mixture of equal weights K_2SO_4 and KCL 0·5% total	K
3.	Urea $CO(NH_2)_2$ (0·5%)	N
4.	Urea phosphate, urea (0·5%) neutralized with phosphoric acid (H_3PO_4)	NP
5.	Potassium salts (0·5%) + urea (0·5%)	NK
6.	Potassium phosphate K_2HPO_4 (0·5%)	PK
7.	Potassium phosphate (0·5%) + urea (0·5%)	NPK
8.	Glucose (0·5%).	
9.	Distilled water.	
10.	Nil.	

As will be seen, the first 7 solutions include all combinations of nitrogen, phosphorus and potassium, one, two and three at a time.

Some idea of the position of the injection hole, and of how long a piece of stem should separate it from the point inside which it is desired to restrict the movement of the injected liquid, can be gathered from Fig. 1, in which the upper label on a branch indicates the position of an injection hole.

As already stated all ten branches on a given tree were selected so that they were as uniform as possible in size and in other respects, but the trees varied definitely in size and, in that half were in their " on " and half in their " off " year. It was not desirable, therefore, to give all the branches the same volume of solution. A satisfactory method for making the dose suit the size of a branch has not yet been worked out. In the absence of a better method use was made of the fact, previously ascertained (1), that, when a tree with mature unfrosted foliage was being injected with nutrient substances such as the ones employed, if the injection was stopped as soon as any signs of leaf damage appeared no serious injury resulted. It will be seen later that urea phosphate behaves abnormally in this respect. As soon as any leaf damage was apparent on a particular tree all the injections on that tree were stopped. In this way an average dose of 1500 cc. of solution was injected.

Table I.

Effect of the Injection of Nutrient Substances on the Shoot Growth of the Branches of Bramley's Seedling.

(The figures in italics in the top half of the Table show the actual number of apples picked from each branch.)

Nutrient injected.		1 P	2 K	3 N	4 NP	5 NK	6 PK	7 NPK	8 Glucose	9 Distilled water	10 Nil
		(A) Length of a single new shoot, cm.									
	Replicates.										
	1	15	19	25	14	14	17	16	14	12	15
		15	*3*	*8*	*0*	*6*	*4*	*12*	*12*	*25*	*15*
"Off" year trees	2	16	13	32	15	17	19	18	11	17	15
		2	*8*	*1*	*0*	*8*	*6*	*2*	*4*	*30*	*16*
	3	15	13	23	17	26	17	18	13	22	20
		10	*20*	*7*	*1*	*3*	*6*	*30*	*9*	*15*	*11*
	Totals	46	45	80	46	57	53	52	38	51	50
		27	*31*	*16*	*1*	*17*	*16*	*44*	*25*	*70*	*42*
	1	12	12	14		22	13	12	6	12	13
		16	*1*	*11*		*3*	*0*	*3*	*37*	*14*	*30*
"On" year trees	2	11	15	13		14	12	10	16	13	12
		34	*23*	*23*		*9*	*2*	*11*	*17*	*19*	*21*
	3	14	15	13		19	12	15	10	14	14
		18	*44*	*28*		*9*	*14*	*6*	*28*	*30*	*26*
	Totals	37	42	40		55	37	37	32	39	39
		68	*68*	*62*		*21*	*16*	*20*	*82*	*63*	*77*
	Grand Total	83	87	120		112	90	89	70	90	89
		(B) Length of new shoot per 100 cm. old wood, cm.									
"Off" year trees	1	45	40	36	19	23	30	23	24	15	12
	2	20	18	65	12	16	30	32	6	27	38
	3	12	19	54	21	67	30	24	13	34	30
	Totals	77	77	155	52	106	90	79	43	76	80
"On" year trees	1	24	12	18		11	3	14	2	7	20
	2	32	30	29		44	27	18	6	14	15
	3	31	11	17		31	25	38	9	28	38
	Totals	87	53	64		86	55	70	17	49	73
	Grand Total	164	130	219		192	145	149	60	125	153

Conclusion.

The distributions resulting from injecting 54 branches with substances in non-toxic, or only slightly toxic, concentration were as predicted ; and only in one (see Fig. 2) of the 6 branches injected with a toxic concentration of urea phosphate did the liquid spread farther. The growth responses to the injections seemed quite definite. Unfortunately bud counts were not taken, but there is no reason for supposing that bud- or fruit-drop was affected enough by the injections to be the immediate cause of the growth increases. The actual number of apples picked from each branch is shown in italics below the growth figure in the top half of the Table.

FIG. 1.

Showing some of the individual branches injected on a tree (22 year Bramley's Seedling). The upper label on a branch indicates the position of the injection hole and the lower label indicates how far signs of leaf damage occurred below the injection hole.

FIG. 2.

Showing the branch (on an " on " year tree) injected with a toxic concentration of urea phosphate in which the solution spread farther than was predicted. The upper label on the branch indicates the position of the injection hole, the arrow marks indicate how far leaf damage spread ; but no bark damage spread beyond the region indicated by the lower label on the injected branch.

Summary.

1. Fifty-four branches of apple trees which had not been spur-pruned were injected with solutions of nutrient substances.

2. All except one of these solutions remained in the injected branch.

3. Urea caused a big increase in shoot growth (in the " off " year trees) and there were smaller increases resulting from the injection of urea plus potassium salts in both " on " and " off " year trees. Glucose caused a decrease of shoot growth.

4. The toxic effect of " urea phosphate " was more severe on the branches of the " on " year trees than those of the " off " year trees.

5. These results encourage the hope that branch injection may become a useful method in physiological experiments.

Acknowledgment.

The writer is indebted to Dr. W. A. Roach for his unfailing interest and advice during the progress of the injection work.

References.

(1) Hearman, J., Levy, B. F. Goodman, and Roach, W. A. " Tree Injection, 1935 experiments." A Progress Report. E. Malling Res. Sta. Ann. Rep. for 1935 (1936), 137-41.

(2) Roach, W. A. " The injection of individual branches of a tree independently of each other." E. Malling Res. Sta. Ann. Rep., for 1936 (1937), 160-6.

THE INJECTION OF WHOLE TREES

By W. A. ROACH

THE injection of trees with liquid through a hole bored in the stem has been carried out for various purposes since Leonardo da Vinci attempted to introduce arsenic into the fruit of a peach tree by injecting the stem. The literature, key references to which will be found in an earlier paper (1), is too extensive for an adequate review to be attempted here. The importance of boring the hole in the correct position in respect to the branches has already been pointed out (1). The present paper will give a short description of the principles underlying the choice of injection points and will give practical details of how to carry out the operation.

Whole trees may be injected by leading the liquid through rubber tubing from a reservoir, placed in the crutch or hung on a branch, to a hole or holes drilled in the correct positions in the main stem. For small trees use may be made of the apparatus already described for injecting branches (see p. 163). Apparatus suitable for large trees is shown in Figs. 1 and 2. The most convenient reservoir A is made by drilling two holes in the bottom of a plywood bucket,* soaking it in molten paraffin wax and, while the wax is still hot, pushing into the holes short lengths of stainless steel tubing,† so that the ends are flush with the inside of the bottom.

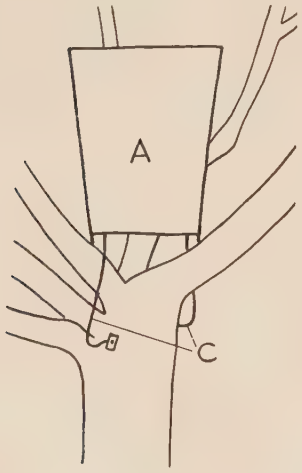

FIG. 1.

Lengths of rubber tubing‡ C (Figs. 1 and 2), connect the ends of the stainless steel tubes protruding from the bottom of the bucket to the rubber block§ D, which has previously had two holes, as shown in Fig. 2, drilled in it with a rapidly rotating metal drill. The end of the rubber tube fits into one of these holes and the two are stuck together with rubber solution. A short length of glass or stainless steel tubing E inside this end of the rubber tubing prevents the walls of the hole collapsing under pressure. This block makes a water-tight joint with the bark F on one side and, on the other, with the rubber pad H (cut from an old motor tyre inner tube) which makes a water-tight joint with the shank of the No. 8 wood screw J, the point of which engages in the blind end K of the hole and supplies the "purchase" which enables the head to hold the block of metal L so that it in turn holds the two rubber pieces D, H, together and presses the block D sufficiently tightly to the bark to prevent leakage of water. The liquid flows through the rubber tube, between the shank of the screw and the rubber block D, and then in the space between the screw and the wall of the hole in the tree trunk.

* Such buckets may be obtained from Messrs. Venesta, Ltd., Vintry House, Queen Street Place, London, E.C.4. Type A capacity 1,219 cu. in. 22s. 9d. per dozen, capacity 619 cu. in. 18s. 3d. per dozen.

† 2 mm. diameter, obtainable from Messrs. Accles & Pollock, Oldbury, near Birmingham, and costing about 1d. per inch.

‡ R.S.C. (red steam cured) valve tubing obtainable from Messrs. Dunlop Rubber Co., Cambridge Street, Manchester, at 12s. 8d. per lb. of approximately 90 yards.

§ Rowney's "R" grey rubber, obtainable from most stationers at 3d. per piece.

When dealing with small trees (say up to 3 in. in diameter or 9 in. in girth) a single hole is bored diametrically through the main stem. When the trees are larger two holes are bored radially nearly half-way through the main stem. For small trees the diameter of the hole must be varied according to that of the main stem (see Table I) ; for trees of 3 in. diameter and above a uniform diameter of $\frac{1}{4}$ inch may be employed. Such holes heal up completely during the current season. Rather than increase the diameter of the holes for trees of greater diameter than 8 in. (or of greater girth than 25 in.) it is better to bore three or more holes, which need not be deeper than $3\frac{1}{2}$ in. for any orchard tree since the central rings not cut by such a hole usually do not conduct injected liquid.

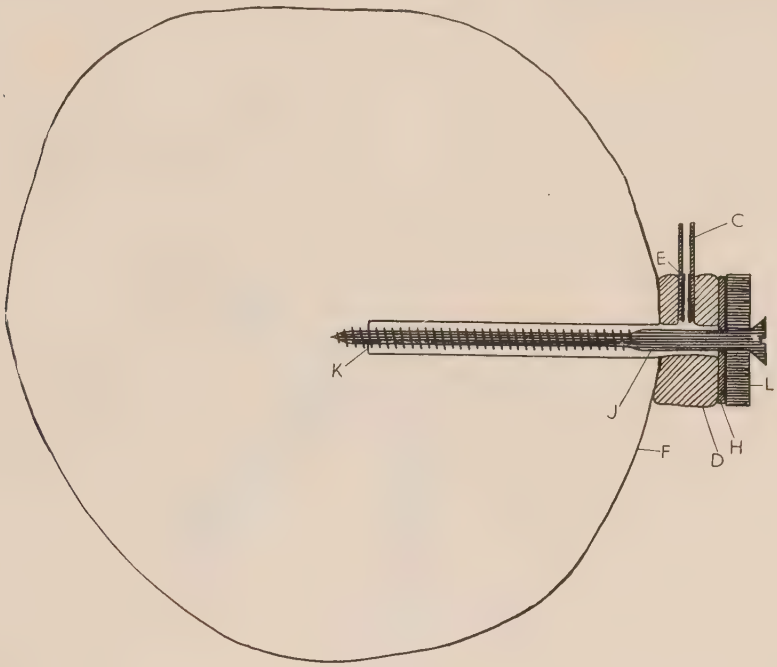

Fig. 2.

When injecting a tree in which the main branches arise close to each other from a main crutch, the mouth of each hole must be " below " the junction between two branches, due allowance being made for any twist in the stem. Because of the " uncertainty of aim ", consequent on the possibility of a twist in the stem, it is best to make the holes as close to the main crutch as possible. They must be spaced as uniformly as possible around the main stem so that the top is divided as nearly as possible into equal portions.

The reason for placing the holes in this way may be seen in Fig. 3 which is drawn looking vertically downwards on the main crutch of a bush-trained tree. The five branches have been cut off just above the crutch and the cut ends of their stumps are seen at A, B, C, D, E. The main stem is drawn as if expanded at the base. The lines such as 1, 2, running from the cut ends of the branches to the base (i.e. the periphery of the figure) indicate the directions along which injected liquid travels most rapidly; these are also the lines along which splits tend to run and along which long thin strands of wood may be split from the tree. It is convenient to say that the injected liquid travels along

these woody strands. Strands 1 and 2 lie side by side in the main stem and when they pass between branches A and E, but when they nearly reach the centre of the main crutch they divide, 1 going into A and 2 into E. The upper part of strand 2 lies side by side with that of strand 3, the lower end of which lies next to strand 4, which travels into branch D. As already stated, injected liquid travels most rapidly along the woody strands, but it does travel quite appreciably from strand to strand circumferentially. It is apparent, therefore, that liquid injected through a hole which cuts through strands 1 and 2 will enter, not only branches A and E, but also branch D.

It will be noticed that branch E is fed by a single undivided group of strands, i.e. by strands 2 and 3 and the ones between them; and branch D is fed by a

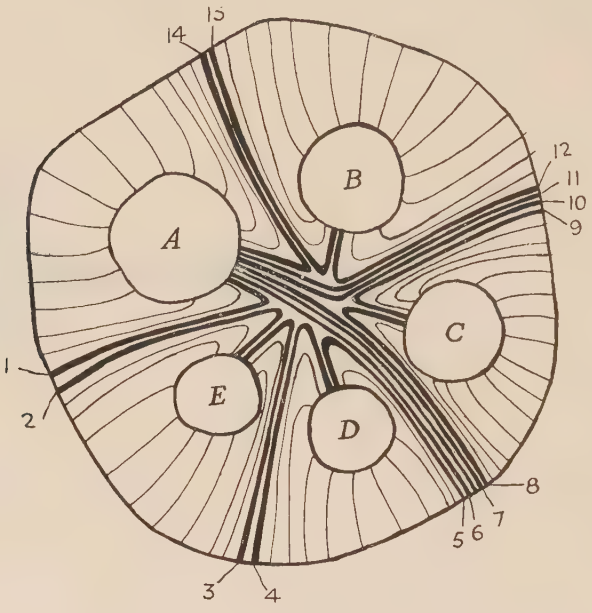

Fig. 3.
(Reproduced with certain alterations by permission from the Annals of Applied Biology.)

similar undivided group of strands 4 to 5; and the same is true of branches C and B, which are fed by strands 8 to 9 and 12 to 13 respectively. Branch A, on the other hand, whilst being fed mainly by strands 1 to 14 is also fed to a smaller extent by strands 6 to 7, which pass down between branches C and D into the main stem, and to a smaller extent still by strands 10 to 11, which pass down between branches B and C into the main stem. The main branches of bush trees commonly vary in size; and when they do, the largest one, like branch A, may have, in addition to its main group of strands, one or more smaller groups passing down between the other branches into the main stem.

Liquid injected through a hole made to cut the strands 10 to 11 will travel along them into branch A and into strands 9 and 12 and along them into branches C and B respectively; and from these strands it will travel into strands 13 and 8, thence into strands 14 and 7 and into branch A. The ends of the hole, or holes, being placed in this

way between 1 and 2 and between 10 and 11 respectively, divide the tree into two nearly equal halves and the injected liquid, as we have seen, permeates the numbered strands, which are drawn heavily, and enters all five main branches of the tree. As the injection proceeds these bands of injected strands broaden ; and when any one of them enters the crutch between two secondary branches into which one of the main branches divides, it not only travels up the inside of each secondary branch, but it also travels down the other side of the main branch as a " streamer " in the same way that the injection of strands 1 to 2 led to the injection of strand 3, not only upwards, but also downwards into the main stem and thence into roots. The progress of the injection, therefore, consists of the gradual broadening of the bands, originally ascending the main branches, and the frequent formation of descending streamers, which also broaden. Usually within an hour or two of the injection being started, the whole tree is permeated with the injected substance.

There is only one way of dividing the above tree in two approximately equal halves ; often there is a choice between two or more possible ways. When there is such a choice it is best to avoid positions of the holes in which strands are cut such as 10 to 11, and even more so broad bands of strands such as 6 to 7, otherwise the leader branch will absorb more than its share of the liquid. Each tree presents its own problem, which, however, may usually be quickly and simply solved. Occasionally it is not possible to divide a tree into two even approximately equal halves. Such a difficulty would have arisen, for example, had branches A, B, C, D and E been equal in size. The ends of the holes would then have been placed slightly nearer to E and C than to A and B, instead of being exactly between them. Sometimes use may be made of the fact that a main branch divides into two above the main crutch in such a way that if one injection hole is bored below this secondary crutch a streamer from it reaches the main crutch.

The placing of the holes for bush-trained trees rarely presents any serious difficulty, but it is more difficult to obtain uniform distribution throughout all the branches of a leader-trained tree and more difficult still in an untrained tree. In such trees it is sometimes a convenience to place a hole in the leader branch just above a main side-branch. The successful injection of such trees, even more than that of bush-trained ones, must be based on a mental picture of the arrangement of the bands of strands supplying each branch and how all these are fused to each other in the main stem ; and on the ability of the worker to be able to picture the distribution of liquid likely to result from an injection at any given point. This, like many horticultural arts, comes much more easily from personal instruction than from reading and follows best from experience.

The above general principles governing the placing of the injection holes have been tested on some hundreds of trees and seem to be well established; and it seems unlikely that further experience will necessitate either modifying or adding to them to any great extent. What at first sight appears a simple problem, namely, how best to drill the holes, is not settled quite so finally, in all probability. The methods in use last year were quite satisfactory but work is still being continued in the hope of improving them still further. The difficulties have been mentioned on another page (p. 164). For small trees the methods already described are quite satisfactory and for larger trees the necessary holes of $\frac{1}{4}$ in. diameter may be drilled with specially mounted metal drilling bits ; but there are two drawbacks to this method : the bit must be withdrawn occasionally to free the wood borings ; and the operation is somewhat laborious. But perfectly " clean " holes may be made by this method. As an alternative the metal-drilling bit may be replaced by a wood-boring one of the Irwin pattern. Few of the bits of this type on the market are capable of cutting a " clean " hole in green wood. We have found some made by the

Irwin Auger Bit Company themselves satisfactory. One of the two commonest faults are these : the flutes of most bits make too acute an angle with the side of the hole, with the result that the borings tend to be churned against the side of the hole instead of being drawn out. The edge of the flute away from the tip should feel definitely sharp. Another common fault is for the cutting edges at the tip to be badly shaped and not properly sharpened. We have found it necessary to remedy such defects with a Swiss file of the finest grade ; and the bits should be sharpened occasionally with the same type of file.

Such bits vary in their " bite ", so that it is necessary to exert slight pressure on some whereas others must be held back a little to prevent the screw at the tip drawing them in faster than they can clear the wood borings out of the hole ; otherwise clogging results. With a little experience the rate at which the bit " bites " can be adjusted by the " feel " and it can be regulated so that the borings come away at a uniform rate. The bit should be withdrawn immediately and cleaned if the stream of borings ceases ; otherwise clogging and faulty uptake of liquid result and the hole actually takes longer to drill. A hole 3 in. or 4 in. deep may be drilled in three or four minutes.

The actual order of procedure which we have found most convenient is as follows :

When many trees are to be injected it is a convenience to decide on the positions for the injection holes beforehand, marking them with paint or with pins which Messrs. Kodak supply for pinning out films to dry. The heads of these pins, being made of white metal, are conspicuous against the dark bark as background. The exit tubes from the reservoirs are closed temporarily with short lengths of rubber tubing plugged with glass rod. They are each placed in the crutch or suspended from a branch so that the tubes will be in convenient positions in relation to the holes ; and the liquid is poured into them. After all the reservoirs have been placed in position, and filled the actual injection is carried out. It is a convenience to have all the tools in one shallow box and sufficient "parts" such as rubber blocks with tubes attached, screws of suitable sizes, etc., in another box. These boxes should be divided into convenient compartments so that each tool and set of parts has its proper place ; and they should have a central handle for carrying. The girth or diameter of the tree is measured and a drill of suitable size is selected after reference to a copy of Table I or II, which should be fixed to one of the boxes. If the tree is a small one the operation is carried out as described on p. 164, except that the bit has to be " aimed " carefully at the desired point on the farther side of the trunk.

If the tree is a large one Table II is consulted for a suitable length for the screw and depth for the hole. The depth is marked on the bit by a pipe cleaner twisted round it. This is moved more easily and rapidly than the attachment made for the purpose. A screw of proper length is threaded through a metal piece L, a rubber pad H, and a rubber block D (Fig. 2). The hole is now bored. The cap is removed from the nearer stainless steel tube and the rubber tubing is connected to it. The end of the screw is put temporarily in the hole in the trunk so that the rubber block may be put quickly and accurately in position so that its hole fits over that in the trunk. The thumb is placed firmly over the bottom half of the rubber block and the hole in it while the top half is pulled away slightly from the bark to allow the liquid to fill the hole and displace all the air. The screw, with its metal piece L and rubber collar piece H, is pushed into the hole and screwed into the blind end with a ratchet screwdriver until liquid ceases to ooze. If all moisture be removed with a cloth a leak may be detected in a few seconds and remedied usually by tightening the screw. An injection, after the liquid has been poured into the reservoir, takes on the average five minutes a hole, i.e. a total of ten minutes for most large orchard trees.

Table I.

Diameter of Hole to be Bored in Trees of Various Diameters and Girths. All Measurements in Inches.

Branch.		Diameter of Hole.
Diameter.	Girth.	
1	3	1/16
2	6	1/8
3	9	3/16

Table II.

Lengths of Holes and Screws for Trees of Various Diameters and Girths. All Measurements in Inches.

Diameter.	Girth.	Length of	
		Holes.	Screws.
3	9	1	2
4	13	$1\frac{1}{2}$	$2\frac{1}{2}$
5	16	2	3
6	19	$2\frac{1}{2}$	$3\frac{1}{2}$
7	22	3	4
8	25	$3\frac{1}{2}$	$4\frac{1}{2}$

Summary.

Practical details are given for injecting trees with liquid through holes bored in their stems. These refer to :

(1) the placing of the injection points in relation to the branches.
(2) the drilling of the holes.

Reference.

Roach, W. A. " Injection for the diagnosis and cure of Physiological disorders of fruit trees." Ann. Appl. Biol., 1934, **21,** 333-43.

FUNCTIONAL DISORDERS OF APPLES ON THE TREE

By H. HILL

A NUMBER of functional disorders such as internal cork, drought-spot, water-core and tree-pit, which affect apples while still on the tree, are of definite economic importance overseas and, in consequence, much attention has been paid to them in Australia, New Zealand and America. These disorders have been of particular interest to me in Canada and what I have seen since arriving in this country in September suggests that, although the occurrence of such disorders in England may be intermittent and much less severe than in the countries mentioned, the latter two at least do sometimes become of commercial importance. During the past season water-core was especially prevalent, and in the variety Rival cases have been noted where as high as 60 per cent. of the crop was rendered unmarketable. Bitter-pit or tree-pit has also been observed, several varieties being affected to the extent of 30 per cent.

The study of these disorders is complicated, on the one hand by the fact that different names have been given by workers in various parts of the world to what appear to be one and the same disorder, and on the other hand by the fact that the same name has been applied to different diseases. In one instance the same name has been applied to a disorder which can be cured by boron compounds and to one which cannot. Descriptions will, therefore, be given of the main types of disorder and any evidence that a particular one can or cannot be cured by boron or any other treatment will be mentioned.

Internal cork. This disorder often appears when the apple is but half-grown. Fruit affected at this early stage in their growth increase but little in size and often drop badly. Affected apples may be detected on the tree by the blushed or red portion of the apple being somewhat darker in colour than normal. In some varieties, fruit affected early in their growth become markedly deformed or knobby. In other varieties, affected later, there is no external evidence of the disorder. Upon cutting open affected fruit light brown spots of dead cork-like material will be found in the region of the core or scattered indiscriminately through the flesh. In many cases the internal brown spots are surrounded by a green area similar to that shown by the water-core disease described later.

Drought-spot or superficial cork. This type of cork may occur very early in the life of the fruit and those severely affected do not increase in size to any extent. The disorder is characterized by irregular small to large, light brown patches on the skin, similar to sunburn injury. Later these areas become dark brown and show a wrinkled or wavy pattern and, as they grow, become roughened and cracked. The lesions only extend into the flesh a few layers of cells but in severe cases deep cracks or splits are also formed.

Investigations in New Zealand and Canada have found that internal cork and drought-spot are associated with a deficiency of boron and may be controlled by tree

injection, broadcast applications of ¼ to ½ lb. of boric acid per tree or by spraying the foliage with this mineral.

Water-core, also commonly known as glassiness, may be recognized in the early stages or when the disorder is not severe only upon cutting open the fruit ; no external symptoms are evident. Glassy areas may then be observed close to the core, around the vascular bundles or in radiating lines ; they appear to be water or sap injected. Later large areas of flesh may become involved and the disorder progresses outwards to the skin, portions affected attaining the characteristic glassy appearance. If the fruits are severely affected when picked a general breakdown of the tissues occurs in storage, but if slightly affected the water-core areas may disappear or be replaced by a browning. Since the trouble may disappear in storage, if not in a severe form when picked, fruit from affected trees should be harvested as early as possible.

No satisfactory control measures have yet been found but it is considered to be more prevalent on young trees just coming into bearing, especially where high nitrogen conditions prevail. The growth of young trees of susceptible varieties should not be forced by heavy applications of nitrogenous manures. I have found that the injection of a nitrogenous salt directly into the branches of a susceptible variety more than doubled the amount and severity of the disorder compared with water injected or untreated branches, and that the injection of a complete nutrient led to a significant reduction. It has been observed by other investigators that the trouble is more prevalent in wet years, and still other authorities consider that high flesh temperatures of the fruit on the tree are a major factor.

Bitter-pit or tree-pit. Pit symptoms may occur while the fruit is still on the tree or may not show up until the apples have remained in storage for some time. The relationship between tree-pitting and storage pit is not clear, but it is only with the former that this note will be concerned. Tree-pit does not show up until the fruit is half-grown and generally is not evident until the fruit is nearly mature. The first cells to be affected are the pulp cells and from these the disorder works outwards ; so that in the initial stages dark spots may be seen through the skin before an actual depression or pit is formed. The first external symptom is the appearance of slightly discoloured spots on the skin of the fruit, deeper green on coloured portions or on yellow apples, deeper red on coloured fruit. Later, the spots become depressed or sunken ; they are comparatively small and rounded. The brown spots occurring in the flesh are mostly small and are generally confined to a few layers of cells just underneath the skin. The pits are usually more numerous towards the calyx end. Another type of tree-pitting, to which the term blotchy-cork has been applied, is apparently of more common occurrence in this country. In this case the pits are less clearly defined, irregular in outline, larger in size, less sunken, deep green, or mottled green and brown blotchy depressions. Large brown necrotic areas are found in the flesh near the core or close to the surface. This blotchy type of pitting has been observed this past season to considerable extent on the variety Newton Wonder.

Up to the present time there is no evidence, however, that either water-core or tree-pit is associated with a deficiency or may be cured by applications of boron. The injection by Levy and Roach of trees with boric acid as a source of boron, with and without the addition of a complete nutrient, failed to reduce the severity of the bitter-pit symptoms.

The effects of nutrition on bitter-pit and water-core are being studied along similar lines.

Summary.

Descriptions (based on observations made in Canada) are given of drought-spot, internal cork, water-core and tree-pit, functional disorders of apples, affecting the fruit while still on the trees.

Control measures are discussed in the light of our present-day knowledge and a distinction is made between drought-spot and internal cork, which are associated with a deficiency and may be controlled by applications of boron, and water-core and tree-pit for which no satisfactory control measures have yet been found.

PRELIMINARY INJECTION EXPERIMENTS ON BITTER PIT IN APPLES

By B. F. G. LEVY and W. A. ROACH

TREES which previously had borne apples affected with certain functional disorders have recently been cured by injecting boron compounds into their trunks. This result was obtained independently by Atkinson (1) in New Zealand, McLarty (2) in British Columbia and Young and Bailey (4) in New Brunswick, each of whom injected a number of compounds but found that boron ones alone were effective.* The disorders, known under various names in different parts of the world, are described by Hill as internal cork and drought spot (p. 180). This note reports preliminary experiments on the effect of nutrition on bitter pit, a disorder which has been considered to belong to the same group as the one just mentioned ; but the results of these experiments suggest that it is not due to the same cause.

Fourteen-year-old trees of Northern Spy on rootstock IX, growing in a row, were used for the experiment. These had previously borne small crops which were affected with bitter pit while still on the tree. Each of the following solutions was injected into four trees.

1. Boric acid, H_3BO_4 (0·1%).
2. Boric acid, H_3BO_4 (0·1%) + potassium phosphate, K_2HPO_4 (0·5%) + urea, $CO(NH_2)_2$ (0·25%).
3. Potassium phosphate, K_2HPO_4 (0·5%) + urea, $CO(NH_2)_2$ (0·25%).
4. Not injected.

The arrangement of the above treatments among the sixteen trees was derived from a latin square.

The injection was carried out by a method described on p. 174. This is an improvement on the one originally described by one of us (3) which was used, with minor modifications, by the workers already mentioned. The amount absorbed varied from tree to tree but averaged 3 litres of solution. This represents a dose of about 3 gm. of boric acid (0·5 gm. Boron), 15 gm. of potassium phosphate, and 7·5 gm. urea per tree. No injury to the leaves resulted from any of these injections but most of the boron-injected trees had two narrow strips of bark killed, each stretching from one end of the injection hole and reaching the top of the branch above.

The fruit were picked when mature (28th October, 1937) and kept in trays in an open shed until the amount of bitter pit was recorded on 19th November.

* Since going to press, a paper by Jamalainen has appeared in which he states that he also has cured cork disease by injecting boron compounds by the same method.

JAMALAINEN, E. A. "The effect of boron on the occurrence of cork disease in apples." Agric. Expl. Activities of the State, Pub.: 89, pp. 11 (1936).

In the following table, column P shows the number of pitted apples, and column T the total number of apples on each tree :

TABLE SHOWING TOTAL NUMBER OF APPLES (T) AND NUMBER OF PITTED APPLES (P), PER TREE.

Injection.	Nil.		0·1% H_3BO_4		0·1% H_3BO_4 0·5% K_2HPO_4 0·25% $CO(NH_2)_2$		0·5% K_2HPO_4 0·25% $CO(NH_2)_2$	
	T.	P.	T.	P.	T.	P.	T.	P.
Tree No. 1	44	16	45	19	64	50	52	22
2	27	9	12	1	84	49	51	21
3	93	39	14	8	135	95	17	8
4	74	11	79	21	32	19	49	23
Total	238	75	150	49	315	213	169	74
% Pitted	31·5		32·6		67·5		43·8	

None of these treatments had any marked effect on the vigour of the trees and none of them reduced the amount of bitter pit. Actually the trees injected with complete nutrient solutions were more heavily affected than the others. A negative result of this kind cannot be considered conclusive but it does suggest that bitter pit is not cured by boron treatments, and that consequently the cause of this disorder is not the same as that of internal cork and drought spot. This causal difference between the " cork " and the " pit " troubles corresponds with a fairly well-marked difference in symptoms (see pp. 180-1).

SUMMARY.

1. The injection of a complete nutrient solution into apple trees affected by bitter pit did not reduce the severity of bitter pit.

2. Boric acid was without apparent effect on the disorder.

3. This suggests that bitter pit differs causally from the " cork " troubles, which are cured by treatment with boron compounds.

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(4) YOUNG, L. C. and BAILEY, C. F. " Progress Report on the investigations of Corky Core of Apples." Scientific Agriculture, 1936, 17, 115-27.

A TREE INJECTION EXPERIMENT ON THE KEEPING QUALITY OF APPLES

A PROGRESS REPORT

By A. C. HULME,* B. F. G. LEVY and W. A. ROACH

Experiments already reported (1) have shown that tree injection may be used as a method for modifying the chemical composition of the fruit. The following results of preliminary experiments suggest that the respiration rate of the fruit may also be influenced. Since low respiration rate is usually associated with good keeping quality in cold store and vice versa (2), the method seems likely to be of use for investigating keeping quality in fruit.

Twenty-three-year-old bush-trained Bramley's Seedling apple trees growing in a commercial plantation were each injected on 30/7/36 by the method described on p. 174 with one of the following three solutions :

0·5% sodium phosphate Na_2HPO_4.
0·5% urea.
0·5% sodium phosphate + 0·5% urea.

Each solution was injected into two trees and two trees were left untreated for comparison.

After harvesting, two apples of standard size were selected at random from each treatment (one only from the sodium phosphate injected samples) and their respiration rates were determined daily for twenty-one days while kept at 12° C. The results are shown in the figure.

In view of the fact that the determinations were done only in duplicate and because of the variation between duplicates, only tentative deductions can be drawn from these results. Sodium phosphate alone appeared to have no effect on respiration rate. Urea alone raised the respiration rate. The injection of urea has been shown to raise the nitrogen content of the fruit (1) and apples of high nitrogen content usually respire rapidly (2).

The combined injection of sodium phosphate and urea, however, reduced the respiration rate to below that of the untreated fruit. This result suggests that the effect of the balance between nitrogen and phosphorus on keeping quality is worth investigating. The actual keeping quality of the fruit is being investigated.

Summary.

The respiration rates of apples borne by trees which had been injected with solutions of urea and sodium phosphate, both alone and together, suggest that tree injection may be used as a method for investigating keeping quality in fruit, and that the bad effect of high nitrogen content may be counteracted by increasing the phosphorus content ; but these conclusions are only tentative.

* Ditton Laboratory.

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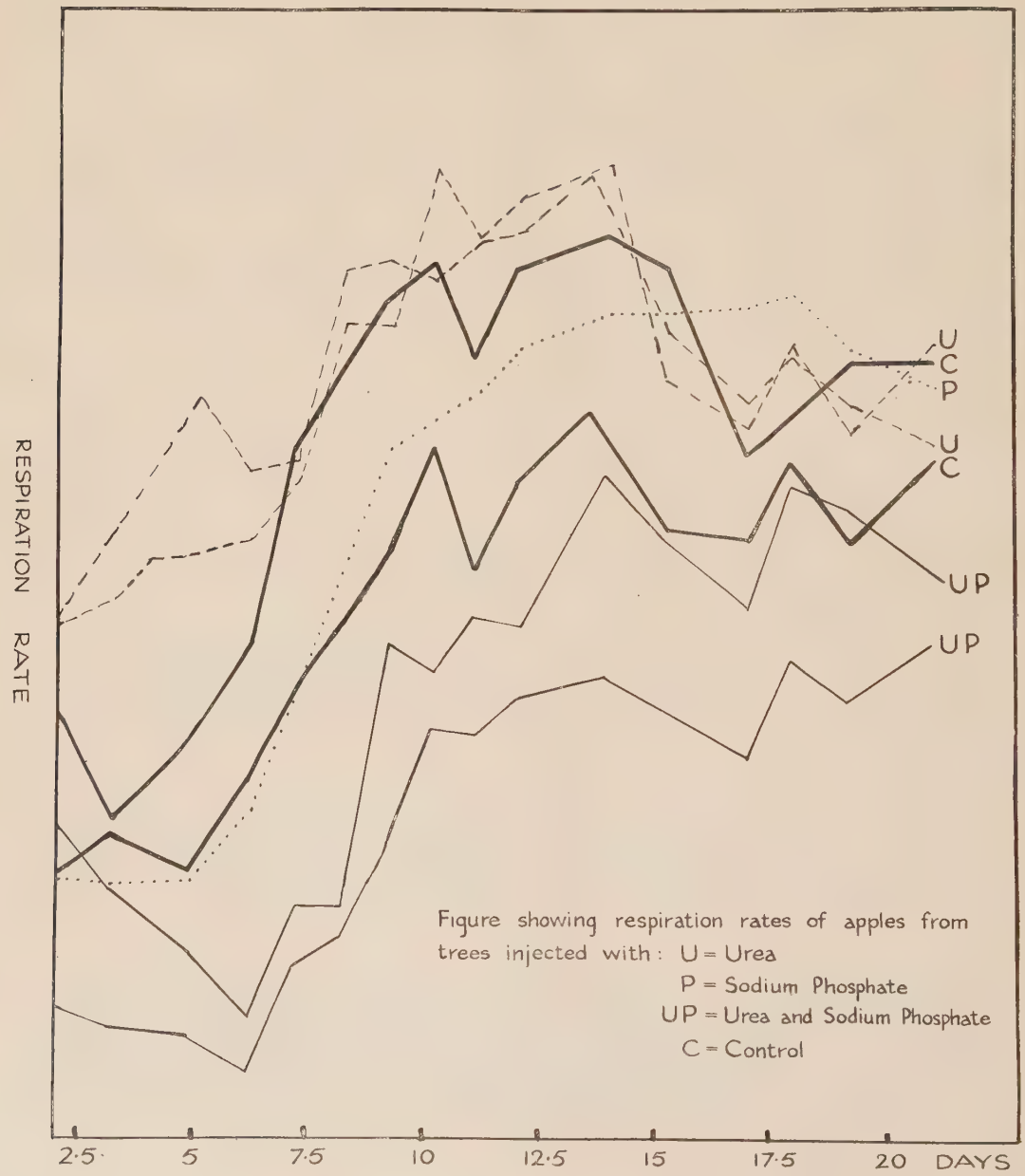


MYCOLOGY AND BACTERIOLOGY

NOTES ON PLANT DISEASES IN 1936

By H. WORMALD and R. V. HARRIS

Non-parasitic Diseases.

A number of fruit diseases not of parasitic origin came to our notice again during 1936, including Bitter Pit, Glassiness (Water-core) and Lenticel Spotting. The variety Rival appears to be very liable to water-core. A grower in Sussex wrote, " My Rivals have always been more or less affected ; this year, however, the percentage was very high and in many cases almost impossible to detect by inspection." In one box he found, on cutting the apples, that about 60 per cent. showed water-core. A grower in Hampshire informed us that 75 per cent. of his Rivals had the same trouble.

In September we examined apples (Warner's King, from Hertfordshire) which showed a splitting at the stalk end. The cracks varied in length from about a half to one inch ; the largest were about $\frac{3}{8}$ inch wide and in apples with cracks of this size one could see right through them. These apples were easily broken along this line of cleavage and they were then found to be split internally ; the sides of this space were greyish and rough but the discoloration was superficial and there was no rot. In some, this space extended only about half way but in others it extended right across the core to the eye-end. The grower said that Warner's King was the only variety affected, so that it would seem that Warner's King is particularly liable to this kind of damage which, apparently, is not a parasitic disease.

The trouble in apples and other fruit trees, called by growers " The Death ", was particularly prevalent in 1936. Trees in many localities of Kent and Sussex were involved; on one farm the losses were said to run into thousands of trees. This disease usually follows a mild wet winter and is often associated with heavy soils and defective drainage. An unusual form of " The Death " was very destructive on one farm in Kent ; in this case the primary cause was probably the severe gales of September, 1935, which loosened the trees in the soil, leaving, round the base of the trunks, a space which became filled with rain and surface water ; this induced a collar rot which killed the trees.

A disease said to be serious in certain parts of North Kent is one affecting the foliage of cherry trees. The general symptoms are rather like those of bacterial leaf spot, as areas in the leaves, often more or less circular, turn brown and drop out leaving " shot holes " ; this, on some leaves, is accompanied by a marginal scorch. In this disease no organism has been found in the tissues of the spots and at present the cause of the trouble is unknown.

Non-parasitic Diseases of Raspberry and Loganberry.

As in 1935 the early part of 1936 was notable for many and widespread outbreaks of disease in this category. Notifications of the great majority of cases investigated were received during May and, as in previous years, it was found that the symptoms consisted of either (1) a " die-back " of individual canes or complete stools associated

with a localized " crown-rot ", or (2) a defective and irregular development of fruiting laterals (" Dwarf-lateral Scorch " of previous reports). In certain cases considerable overlapping of these symptoms occurred in the same plantation and in others one or the other was present almost exclusively.

A striking correlation of the first or " die-back " group of symptoms with defective soil drainage (accentuated by high rainfall and lack of frost action in the winter of 1935-6) was determined.* Severe cases of the latter, or " dwarf-lateral scorch ", group were found to occur on well-drained soils.

The Lloyd George raspberry was conspicuously susceptible to both forms of disease, and the loganberry also. Defective lateral development on the loganberry was particularly prevalent, an exceptionally high proportion of each fruiting bine (from the apex downwards) in such cases being non-productive of normal fruiting laterals. Such " blind-bine " was not, in the present season, associated with concentrated lesions of Cane-spot disease (*Elsinoë veneta*) as commonly found in previous seasons.

Diseases caused by Fungi.

Apple Canker. In July specimens from Monarch apple trees, three years old, on rootstock No. XIII, showed severe cankering (caused by *Nectria galligena*) in the neighbourhood of the bands ; it was estimated that about 75 per cent. of the trees on a ten-acre plantation were affected. On enquiry it transpired that the bands had been made from old nitrate of soda bags and this probably made the trees more conducive to attack, although it was found that trees banded with other materials, such as pieces of old jacket, were also attacked, and some of the spare trees which had been heeled in, and consequently untied, were infected.

Coral Spot Canker on Apple Trees. The Coral Spot fungus, *Nectria cinnabarina*, is a common parasite of red currants and occasionally it is found causing cankers on apple trees. In February a portion of apple branch and a twig bearing the Tubercularia fructifications of *N. cinnabarina* were received from near Colchester. The twig was quite dead and bore the fungal fructifications scattered over a length of five inches. On one side of the branch, which was one inch thick, was a definite sunken canker with a pruning cut at its centre ; the canker was 4 inches long, half girdling the branch, and bore numerous fructifications. On the other side was another sunken canker, nearly half girdling, with fructifications. The grower wrote, " In each case (I have had six) they have been on wet patches of soil while all surrounding trees appear unharmed. The specimen sent was from a Grenadier of which I had three trees affected ; it was also found on two James Grieve and one Laxton's Superb. It appeared first in early summer in the form of die-back in the shoots, affecting them very suddenly, and wilted the whole current year's growth in a few days."

Apple Mildew. A report received from a Surrey nursery suggests that apple scions worked on East Malling rootstock No. XVI, are more susceptible to Apple Mildew (*Podosphaera leucotricha*) than on certain other rootstocks. It was stated that Allington Pippin, Cox's Orange Pippin and James Grieve showed about 50 per cent. of the trees infected with mildew, in other varieties about 25 per cent., while trees worked on Nos. II, IX and XII were not affected.

* This investigation was carried out in collaboration with the County Advisory Officers in Commercial Fruit Growing for Kent and East Sussex and with the soils expert of South-Eastern Agricultural College, Wye, Mr. B. S. Furneaux.

Sooty Blotch of Apples and Plums. This disease, caused by the fungus *Gloeodes pomigena*, was unusually prevalent in 1936 as a result of the cold damp summer, and enquiries were received from various localities concerning its cause and control. Many apples exhibited at shows bore this blemish. The disease occurred also on plums on this Station and probably on other fruit farms too, although no enquiries concerning its appearance on plums came in. On the red and purple varieties it is not very conspicuous but on the yellow-skinned plums it is most unsightly.

A more detailed account of this disease with recommendations for its treatment is given on pp. 194-7 of this Report.

Quince Leaf Blight. This disease, caused by *Fabraea maculata* (=*Entomosporium maculatum*) is not usually troublesome except in wet summers when it may cause severe leaf-fall. One enquiry was received during 1936 from a nursery where quince stocks were showing considerable spotting of the foliage.

An examination of quince layer beds on this Station showed that the varieties used as rootstocks are not equally susceptible. Quince A, although some of the lower leaves were yellowish and very spotted, was far healthier than Quince C, on which many of the upper leaves were infected and there was pronounced leaf-fall in places in the rows.

Verticillium Wilt of Quince Stocks. Specimens of dead two-year-old and maiden pear trees on Quince Malling type C stock and unworked stocks of the same type were received in the latter part of August from a fruit farm in Hampshire. On sectioning the main stem of the stocks at a short distance above the roots, symptoms characteristic of Verticillium attack were found, namely clearly delimited areas of blue-green discoloured wood, in the vessels of which fine fungal hyphae were observed. From this discoloured wood *Verticillium Dahliae* Kleb. was isolated in pure culture. We understand that the proportion of trees in the nursery which succumbed to this disease was relatively small (less than 1 per cent.). It will be recalled that in 1932 an attack of this disease occurred on Quince Stocks Malling types A and C on the Research Station nurseries (see E. Malling Res. Sta. Ann. Rep., 1932 (1933), p. 82).

Wilting of Shoots in Layer Rows of Prunus spp. In the Report for 1935 reference was made to a wilting of shoots in the layer rows of plum, cherry and peach on this Station. The disease had been first noticed in 1932 but in 1935 it was far more serious and in 1936 again many shoots were killed not only in stocks that are being raised for experimental purposes but also in the main plum rootstocks on Newgates Field.

The disease is characterized by a lesion a few inches long on that part of the shoot below soil level; the lesion girdles the shoot, causing the leaves to flag and eventually to wither. The lesion almost invariably bears minute black specks suggesting fungal fructifications; they are almost always barren and appear to be microsclerotia, so that until 1936 it had been impossible to identify the fungus. In June, however, fungal fructifications were found for the first time on lesions on a few shoots in a short layer row of apricot which was being raised for experimental work.* Single-spore cultures of the fungus were obtained and these were similar to cultures previously obtained from the tissues of the lesions and from microsclerotia. The fungus, from its fructifications and spores, conforms to descriptions of *Cylindrocladium scoparium* Morgan,† which causes a Crown Canker of roses in America and in this country.

* This was brought to our notice by Mr. W. F. Chang, a post-graduate working at this Station.

† We are greatly indebted to Miss E. M. Wakefield and Mr. E. W. Mason for their aid in identification.

Professor Massey of Cornell University, U.S.A., kindly sent us a culture of the rose fungus for comparison. We find that in culture the two fungi have different habits of growth so that it would appear that they are not strictly identical.

C. scoparium has been found to infect strawberry roots in Canada,* so that the possibility that the fungus found on Prunus stocks at East Malling may have other hosts is a problem requiring further investigation.

Collar Rot of Red Currants. A number of bushes on the red currant variety plot on the Station became infected at ground level with the fungus *Fomes Ribis*, producing a collar rot which resulted in premature defoliation. Several varieties were attacked and on Hollande Rouge about 30 per cent. of the bushes were affected. In the worst cases the bracket-shaped fructifications coalesced and encircled the collar, forming a mass of sporophores almost as large as a dinner plate. The bushes have now been grubbed.

Leaf Spot of Gooseberries and Black Currants. This disease, caused by the fungus *Pseudopeziza* (*Gloeosporium*) *Ribis*, was more prevalent in 1936 than during the preceding dry summers. Towards the end of July branches of Howard's Lancer gooseberry were brought in by a grower at West Malling. The bushes, we were told, were nearly defoliated and the remaining leaves were very severely spotted ; there was no doubt that the severe infection had caused the older foliage to turn yellow and drop off. A few berries were also brought and on one of these the *Gloeosporium* pustules were present on the fruit stalk and on the berry itself at the stalk end. This disease is usually confined to the leaves and we have not previously seen it on the fruit itself.

During September there was severe leaf spot on the variety trial plot of black currants on the Station. On some varieties the bushes were almost defoliated. The degree of infection shown by four varieties was as follows :—

Boskoop Giant—nearly defoliated ; the leaves remaining on the bushes are nearly all brown and curled.

Baldwin—infection not so severe as on Boskoop but leaves mostly brown and curled.

Seabrooks—foliage in much better condition.

Goliath—stands out from the rest by reason of its foliage which is still green.

Strawberry Leaf-spot. In early May our attention was called by Mr. W. G. Kent to a severe attack of this disease on forced maiden pot plants of Royal Sovereign from a glasshouse in the Swanley district.

A striking feature of this case was a heavy spotting of the petioles and flower pedicels in addition to the leaves. Conidia of the Ramularia stage of *Mycosphaerella Fragariae* were found in abundance on spots from each of the organs in question.

Strawberry Mildew. Mildew (*Sphaerotheca Humuli*) was observed on Royal Sovereign plantations at the Research Station from cropping time onwards, but the attack on the berries was, on the whole, slight, probably owing to the long preceding period of dry cold weather.

The progress of infection remained inconspicuous during the excessively dull rainy mid-summer period, and it was only after a rapid change to settled dry sunny

* See " Fungous Root Rots of the Strawberry," by J. H. L. Truscott, Canadian Journ. of Research, **11,** (1934), p. 10.

weather in mid-August that a serious scorching or red coloration of the older foliage became apparent. This was so severe on certain of the " first-year " runner propagating beds, and to a greater degree on " second-year " beds, as seriously to impede the recognition of virus disease during the final inspections and roguings. For details of control experiments see p. 276 of the present Report.

Fungus Diseases of Raspberry. The season was favourable to heavy infections by Cane-spot (*Elsinoë veneta*) and Spur-blight (*Didymella applanata*). The attack of the former disease on Lloyd George plantations at East Malling was outstandingly severe. The effect of such on the crop will not be apparent until 1937. Cases of the infection of " new-canes " by *Botrytis* sp. were also recorded. Blue Stripe Wilt (*Verticillium Dahliae*) was recorded on many varieties but the attack was, generally, light.

Verticillium Wilt of Hops. This disease is caused by *V. albo-atrum.* The wilting of bines before cropping in gardens of the Fuggle variety affected prior to the present season, was outstandingly severe and was correlated with the unusually heavy rainfall preceding picking.

Five additional outbreaks were also reported and investigated in Kent and Sussex ; these, however, for the greater part, were relatively slight and clearly the result of the seasonal conditions, which were exceptionally favourable for wilt.

Bacterial Diseases.

Plum and Cherry Bacteriosis. Severe losses were experienced in many localities from bacterial infection in plum and cherry trees. As a rule stem infections are not noticeable until the trees come into leaf in spring although the actual lesions are produced during winter. In 1936, however, the disease was brought to our notice as early as the third week in February when parts of the leaders and side twigs of two-year-old Early Laxton plum trees were sent to us from Hampshire. As the trees were being cut back in the nursery it was found that on many of them the bark was discoloured, so enquiries were made as to the cause. On examining the specimens we found that the diseased tissues were swarming with bacteria, and *Pseudomonas mors-prunorum,* the cause of Bacterial Canker in plum trees, was isolated from the lesions. The disease was reported to be present on Victorias also, in the same nursery.

Later in the season, as trees came into leaf, the disease proved to be widespread and very destructive, and various enquiries were received concerning it. In a plantation of Giant Prunes, recently taken over by this Station, about 25 per cent. of the trees had contracted the disease and had to be grubbed.

A severe attack of Bacterial Canker and Leaf Spot of Victoria plum trees in Northern Ireland was brought to our notice by Mr. A. E. Muskett, M.Sc., of Queen's University, Belfast. The symptoms of the disease, and the cultural characters of the organism isolated from the lesions, showed that the disease is the same as that occurring in England. This is the first record of the disease in Northern Ireland.

Bacteriosis was severe in sweet cherry trees also, cankers, shoot-wilt and leaf-spot being more prevalent than usual. Certain varieties have proved to be far more susceptible than others. Among the most susceptible are Bradbourne Black, Waterloo, and Bigarreau de Schrecken, while Frogmore and Governor Wood appear to be comparatively resistant.

In Morellos bacterial leaf-spot, mentioned in the Report for 1935, was far less severe in 1936. This was associated with a rather dry period while the trees were coming into leaf ; the weather conditions at this time are probably an important factor in relation

to intensity of attack. Preliminary inoculation experiments were carried out in the spring of 1936, on Morello buds as they unfolded, using organisms isolated from leaf spots, and evidence was obtained that one of these organisms is able to infect young leaves and produce the leaf spots. This bacterium, on culture plates, produces colonies easily distinguishable from those of the two organisms *Pseudomonas mors-prunorum* and *Ps. prunicola*, causing bacteriosis in plum and cherry trees.

Bacteriosis of Ornamental Species of Prunus. In May specimens from young almond trees were received from a Berkshire nursery.* These showed bacterial lesions on shoots and leaves. From these lesions an organism was isolated which, in preliminary culture tests, shows affinity with *Pseudomonas mors-prunorum* and is probably identical with it, but further culture work and inoculation tests are necessary for confirmation.

A tree of the Purple-leaved Plum (*Prunus Pissardii*)† showing die-back was examined in August and a bacterial lesion found on the stem. An organism isolated (by Mr. M. H. Moore) from this stem canker again appears to be *Ps. mors-prunorum*, and a comparison of the two is being made.

Pear Bacteriosis. Catillac pear spurs, bearing blackened withered flowers, sent to us in May from Essex, were found to contain numerous bacteria, and when isolated and preliminary culture tests applied the organism showed relationship with *Pseudomonas prunicola.*

Later in the season Fertility pear fruits received from North Kent showed circular spots about one-twelfth inch in diameter and up to twelve in number on the worst affected fruits. When particles from these spots were teased out in water and examined microscopically they were found to be swarming with bacteria. Isolations were made and the organism was indistinguishable from that isolated from the pear blossoms.

Both these organisms (from blossoms and from fruit) when inoculated into pear fruits, caused lesions so that it would seem that the organism associated with blossom wilt is also able to infect the fruit.

The relationship of the organisms infecting fruit trees in this country is one requiring close investigation. It is probable, from the observations here recorded, that the two organisms found commonly associated with bacteriosis in plum and cherry trees have other hosts. If this is confirmed by future work it must be borne in mind that each of the various hosts may be a source of infection for others in the vicinity. At least two ornamental species of *Prunus* grown in Britain, Almond (*Prunus Persica*) and the Purple-leaved Plum (*Prunus Pissardii*) appear to be hosts of *Pseudomonas mors-prunorum*. Again, American investigators have recently provided evidence‡ which suggests that the bacteria causing Lilac Blight (*Ps. Syringae*), Citrus Blast (*Ps. citriputeale*), and Blossom Blight of pears (*Ps. utiformica*) may be identical with *Ps. Cerasi* or *Ps. prunicola*, of stone fruit trees, the last-named being one of the organisms causing bacteriosis in plum and cherry trees in Britain. If this relationship should be established it would indicate that Lilac and Forsythia, both of which are attacked by *Ps. Syringae* in this country, may also be a source of infection for fruit trees. The possibility of one species of plant harbouring a disease which may pass over to another species is of importance not only in orchard management but particularly in nursery work where young trees of various species are grown in close proximity.

* We are indebted to Mr. W. Buddin, M.A., of Reading University for sending us these specimens.

† Kindly sent by Dr. Barratt, Principal of the Horticultural College, Swanley.

‡ See particularly, " Symptomatic and Etiological Relations of the Canker and the Blossom Blast of Pyrus and the Bacterial Canker of Prunus," by Edward E. Wilson. Hilgardia, 10, No. 8, November, 1936, pp. 213-40.

A maiden plant of Royal Sovereign Strawberry (under forcing in greenhouse) with severe attack of *Mycosphaerella Fragariae* on leaves, petioles and pedicels.

Crown-gall. The occurrence of galls on a number of plants, suggesting infection by the Crown-gall organism, has been mentioned in previous Reports, but further investigation is necessary in order to determine whether *Bacterium tumefaciens* is really the cause of the galls in every case.

During 1936 specimens were received of *Asparagus Sprengeri* (sent by Mr. W. E. H. Hodson from Middlesex), bramble (sent by Dr. G. H. Pethybridge from Hertfordshire), and phlox from a Maidstone garden, bearing galls which appear to be of the Crown-gall type. On the asparagus the galls were up to 1·5 cm. in diameter, mostly at ground level but many above ground, chiefly at the nodes. The bramble specimen was a portion of cane bearing two galls, one about 1 cm. in diameter, the other measuring 2·5 by 3·5 cm. The phlox stems bore numerous small galls from ground level to about one foot upwards.

Virus Diseases.

Strawberry Virus Diseases. Symptoms of Crinkle (both the mild and severe phases) were observed on Royal Sovereign from early May onwards, but it was not until the latter end of May that definite Yellow-edge symptoms were seen on this variety and then only rarely and on older (three-year-old and upwards) plants.

At the end of June and onwards Yellow-edge symptoms began to develop on a small proportion of maiden and older plants known to be infected.

In early July diagnosis was complicated in field plantations by the widespread development of a leaf chlorosis (" pseudo-yellow-edge ") which diminished as the season progressed and was clearly not of virus origin, being attributed rather to rapid transition in mid-June from an abnormally prolonged spring period of dry cool weather with persistent N.-N.E. winds, to warm thundery conditions with heavy rainfall.

Yellow-edge symptom expression continued to progress slowly until mid-August, when a temporary regression took place following the period of dry warm weather which supervened, and reached its maximum at the end of September when conditions were ideal for " roguing " runner-beds, remaining so until late October.

Summary.

Certain non-parasitic, fungal, bacterial, and virus diseases observed during 1936 on fruit trees and bushes are noted. Special attention is drawn to Dwarf Lateral Scorch in raspberries, Sooty Blotch of apples and plums, a wilting of shoots in layer rows of *Prunus* spp., bacterial diseases of plum, cherry and pear, Verticillium wilt of hops, and strawberry Crinkle.

THE SOOTY BLOTCH DISEASE OF APPLES AND PLUMS

By H. WORMALD

The disease of apples known as Sooty Blotch was very prevalent during the late summer and autumn of 1936, and many enquiries were received with regard to its cause and control. Sooty Blotch was found on fruit exhibited at shows and the disease was evidently widespread and causing some concern. It was also seen on a number of varieties of plums on this Station, in some cases, as on Warwickshire Drooper and Pershore Egg, causing very marked disfigurement which reduced considerably the market value of the fruit.

Sooty Blotch is caused by the fungus *Gloeodes pomigena* (Schw.) Colby. As the common name implies the affected fruit bears smoky or sooty smudges as if it had been handled by someone with sooty fingers. The blotches are brown or greenish, usually more or less circular, and about a quarter of an inch in diameter, though in some cases they may coalesce and cover the greater part of the surface of the fruit. Typical blotches, when examined with a lens, show numerous minute specks (which are dense aggregations of fungal cells) and this character usually serves to distinguish Sooty Blotch from Scab, with which it is sometimes confused. At times, however, these cell aggregations are absent and the blotches have a more uniform structure. The fungus of Sooty Blotch is more superficial than that which causes Scab and does not cause the cracking and malformation that so often accompany a severe attack of Scab.

This disease on apples has been known in Britain for a number of years. It was first recorded for this country by Professor Salmon in 1910 (3). During recent years it has fluctuated in intensity and it is evident that the degree of infection bears some relation to the weather conditions during summer. In cold wet summers the disease is worst, while during years in which sunshine is above the average and rainfall relatively low the disease may be unnoticed. It was very prevalent in 1927. The dry summers of 1928 and 1929 checked its spread and the damage was negligible. It was very severe in 1930, and again in 1932 when the late summer and autumn were very wet, while the attack in 1936 would appear to have been even worse. It is also worst on the shaded parts of the trees, particularly therefore on those branches in the middle of the tree or on the north side, and where branches are allowed to grow too crowded.

The variety of apple most susceptible to Sooty Blotch in this country appears to be Bramley's Seedling ; severely infected fruit of this variety were seen in 1927 and 1932 as well as in 1936. Cox's Orange Pippin is also sometimes badly blotched. Other varieties on which it has been found are Blenheim Orange, Allington Pippin, Lord Derby, Lane's Prince Albert, Belle de Boskoop, King Pippin, Laxton's Superb, Sanspareil, Charles Ross, Barnack Beauty and Christmas Pearmain, so that it would seem that most of the commonly cultivated commercial varieties are more or less susceptible to this disease.

Sooty Blotch occurs also on pears, the first record of its occurrence on this fruit in Britain being a brief account, in the Gardeners' Chronicle in 1916, describing its appearance on Catillac Pears (4).

On plums it was observed at this Station in 1930 and a note to that effect appeared in the Report for 1928-30 (5). In some seasons it has been severe, as in 1932 and in 1936. The variety Warwickshire Drooper is the one on which it is most conspicuous ; on this variety in 1936 the disease was present on about 90 per cent. of the fruit. The worst affected fruits were small, the whole or almost the whole of the surface of such plums being covered with the fungus. Plums severely affected began to shrivel some time after they were picked and on keeping such fruits some shrank and became wrinkled, in contrast to the rounded firm appearance of the healthy plums. Very many fruits of this variety had a half to three-quarters of the surface covered, the infection being worst at the stalk end.

The blotches were also very conspicuous on Pershore Egg, another variety with a very pale skin. On varieties with darker skin, such as Victoria and Pond's Seedling, the markings were not so clearly shown but the presence of the fungus definitely detracted from the appearance of the fruit and reduced its market value. Other varieties of plums on which Sooty Blotch has been found are Cambridge Gage and Giant Prune.

Sooty Blotch has proved troublesome to American growers and it has, in consequence, been studied by a number of investigators in that continent. It has been found that the ordinary routine spraying with Bordeaux mixture or lime-sulphur will help to keep the disease in check, and observations at East Malling in 1936 showed that there was considerably less Sooty Blotch on the fruit of trees that had received the routine sprays (lime-sulphur once before blossoming and twice afterwards) than on unsprayed trees. A third post-blossom spray that some plots received probably had its effect in keeping the disease within negligible limits, although it was so prevalent in many parts of Kent and in other counties.

For use when spraying has been neglected or has not been effective in keeping down Sooty Blotch, methods have been devised for treating the fruit after it is picked. Colby (2) recommends treating blotched apples with Javelle Water prepared as follows : 4 lb. of bicarbonate of soda are put into a kettle over a fire, 1 gallon of boiling water added and let boil ten to fifteen minutes when 1 lb. of chloride of lime is stirred in ; the mixture is used when cool. The blotched apples are immersed in this for three to six minutes, then well washed in running water and allowed to dry.

This method was tried in 1930 on Warwickshire Drooper plums ; after immersion in the fluid some were washed for half an hour, others for an hour and a half. The former smelt strongly of chloride of lime and the skin had a distinct flavour of it, although the flesh appeared to be free from objectionable taste. Of those washed for one and a half hours the skin had a very slight flavour and taste of the chloride. The treatment bleached the fungus and rendered the blotching far less conspicuous.

The method was tried again, in 1931, the fruit after treatment being divided into three lots which were washed for one hour, one and a half hours, and three hours respectively with almost similar results ; all the samples smelt and tasted of chloride of lime, so that it seems unlikely that this method will be of any value for plums.

A modification of the Javelle Water method is recommended by Miss A. M. Bottomley (1) in South Africa where Sooty Blotch is becoming troublesome not only on apples but also on citrus fruits. Miss Bottomley writes, " The method in use for the removal of Sooty Blotch from apples consists in dipping the latter in a solution of bleaching powder, and then, after exposing them to the air for a short while, washing them and allowing them to dry." Experiments were carried out and as a result " it was found that a one-minute dip in a 5 to 6 per cent. solution of bleaching powder (calcium chloride), followed by a five to ten-minute exposure, effectively removed the black blotches and at the same time did not in any way adversely affect the fruit."

Miss Bottomley's method is simpler than that involving the preparation of Javelle Water and as it is less drastic, the dipping being only for one minute, it seemed possible that it might be used on plums without leaving an objectionable taste in the fruit. In 1936 when blotched fruit again became available, the method was tested at East Malling on plums and also on apples. The mixture was prepared by simply adding the bleaching powder to water at the rate of $\frac{1}{2}$ lb. to the gallon (5 per cent.), stirring well, and leaving to settle for a few hours or overnight. The clear liquid was then decanted or siphoned off for use. As the experiments were only on a small scale the fruit was placed in muslin bags and suspended in these in the liquid for one minute, after which they were taken out and spread on a bench for ten minutes, then well washed in tap-water and left in the air to dry.

The plums (Warwickshire Drooper) treated in this way were very much brighter in appearance than the untreated ones and although the blotches were not removed they were rendered inconspicuous. Moreover, no smell or taste of the bleaching powder could be detected on the treated plums.

The apples used in the test were Bramley's Seedling severely infected with Sooty Blotch, and kindly provided by a grower who had enquired about the disease. The sample, about a bushel, was divided into three lots, one lot kept untreated as controls, another was treated according to Colby's Javelle Water method, and the third with Bottomley's method ; a few apples were merely washed with water as a further control. Both treatments gave good results. The apples treated with Javelle Water were rather brighter looking than those receiving Bottomley's recommended treatment, but the latter's method is so much simpler to carry out that it is to be preferred, even for apples, especially when large quantities are to be treated.

The treated and untreated apples were put into storage and examined in March, when it was found that the treated apples had remained clean, while on the untreated fruit the fungus had continued to develop so that these apples were far more severely blotched than they were when put into storage. The treatment, therefore, not only cleans the fruit but prevents further development of the blotch.

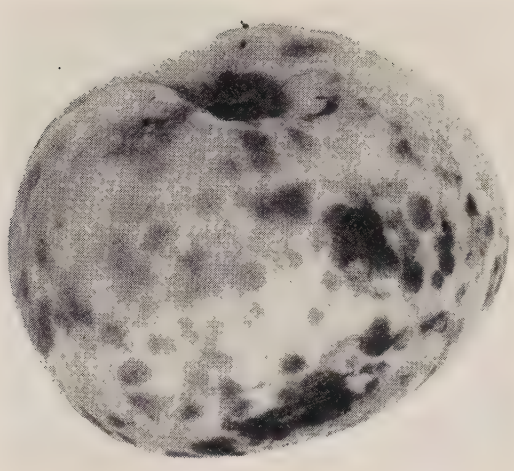
This method has not been tried here on a large scale so details as to the best procedure are not available. It is suggested, however, that for large quantities of fruit shallow trays (or baskets) be loaded with the blotched fruit, immersed in the bleaching fluid, taken out, and the fruit exposed to the air, washed and dried, before it is finally removed from the trays for marketing or storing.

There is yet another method which may be used for relatively small quantities of apples, but it is probably not suitable for the smaller and softer plums. Rubbing the apples with a damp cloth will remove much of the blotching and can be employed if found convenient, but each apple has to be handled separately and this makes the procedure an arduous and lengthy one when large quantities are to be treated. One grower informed me in 1932, a year when Sooty Blotch was prevalent, that, out of fifty to sixty boxes of Bramley's Seedling, he had to clean about 50 per cent. of the apples in this way before he could market them, so the method would appear not to be an impracticable one.

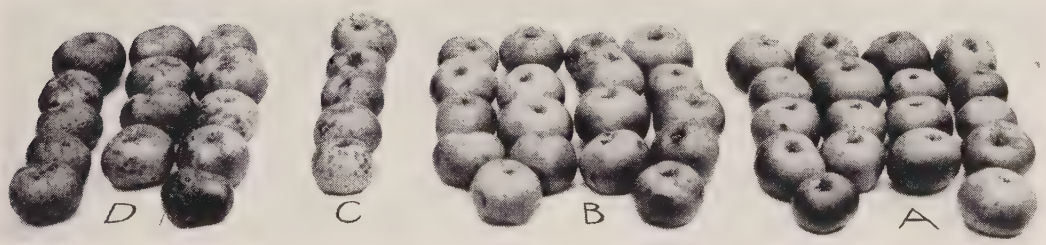
Summary.

Sooty Blotch of apples, caused by the fungus *Gloeodes pomigena* (Schw.) Colby, was very prevalent in many parts of England in 1936, and the same disease was serious on certain varieties of plums at East Malling.

Two methods of reducing the blotching by bleaching have been tested at East Malling and the simpler one, as recommended by Bottomley, gave satisfactory results



Sooty Blotch on Bramley's Seedling Apple



Sooty Blotch on Bramley's Seedling Apple.

A—4 mins. immersion in Javelle Water, followed by ½ hour in running water. B—1 min. immersion in 5 per cent. Chloride of Lime Solution followed by 10 mins. exposure to air, then washed for ½ hour in running water. C—Washed in cold water for 5 mins. D—Untreated.

on a small scale with both apples and plums. Recommendations for treating larger quantities are suggested.

Cleansing the fruit by rubbing with a damp cloth can be employed as an alternative treatment when the quantity of fruit to be treated is small enough to allow of individual treatment.

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(3) Salmon, E. S. "Sooty Blotch, a new fungous disease of apples." Gard. Chron., 1910, **48,** 443.

(4) ——— and Wormald, H. "Sooty Blotch of the Pear." Gard. Chron., 1916, **59,** 58-9.

(5) Wormald, H. "Sooty Blotch." E. Malling Res. Sta. Ann. Rep. for 1928-30 (1931), II. Supplement, 127-8.

FURTHER OBSERVATIONS ON BROWN ROT OF PLUMS IN COLD STORAGE

By H. WORMALD and A. C. PAINTER

In 1934 observations were made on the rotting of plums in cold storage, and the results were published in the Report of this Station for that year. It was found that the wastage by rot was caused chiefly by the common Brown Rot fungus *Sclerotinia fructigena*, but that *S. laxa* was partly responsible, while fungi of more saprophytic habits, such as *Botrytis cinerea* and species of *Mucor* and *Penicillium*, were also present on the fruit and contributing to the wastage.

It was considered desirable to obtain confirmation of these results by taking similar observations during a second season. This was not possible in 1935 owing to the lack of fruit as a result of the severe late frosts about the middle of May that year, but in 1936 plums again were plentiful enough to be stored. The fruit was picked and placed in cold storage on the same or the following day and taken out for marketing from 13 to 34 days later.

Only undamaged fruits in firm or fairly firm condition was stored. The plums were placed three to four deep in shallow trays lined with paper, each tray holding about 30 lb. of fruit. Plums without stalks were not excluded as this would have involved the rejection of too much fruit.

Endeavour was made to keep the fruit in store at 34° F. but, owing to the frequent opening of the doors for loading and unloading, it was not found possible to maintain this temperature, and the average was nearer 35° to 37°. Moreover, a choked strainer caused a rise to between 38° and 42° during the period 22nd to 26th September. This undoubtedly had a considerable effect on the storage life of the fruit.

When taken out of storage it was found that the fruit could be divided into three categories, (*a*) sound fruit, (*b*) those that were over-ripe, and (*c*) fruit which was affected by rot.

The plums examined first were Victorias, picked on 28th August and placed in cold store the next day ; they were transferred to cool storage on 9th September, and the sound fruit sorted out and sent to market on 10th September.

In order to determine the cause of the rotting a random sample was taken from the fruit placed in that category and a closer examination made. Some of them had no external signs of fungus, others bore tufts of whitish mycelium but no definite fructifications, and a few only had mycelium bearing chains of Monilia spores. Very few of the tufts could be distinguished, by their colour, as *S. fructigena* or *S. laxa*.

On 11th September these plums were placed in baskets, a single layer in each basket, and the fruit placed so that no two of them were in contact, to allow of free aeration and to prevent any further infection by contact. The baskets were then exposed to daylight in a well-lighted window to induce the fungi to produce their fructifications and so facilitate identification. Within three days the white fluffy mycelium, which had developed in the darkness of storage, was becoming replaced by definite fungal fructifications, and on 14th September it was possible to identify the fungi on nearly all the plums, for out of a total of 111 in the sample only eight showed no fructifications, but two days later seven of these also bore fructifications. It was assumed that the

remaining one fruit was not attacked by any fungus and that its condition was due to over-ripeness only.

The fungi present were the same as those found under similar conditions in 1934. *S. fructigena* predominated and *S. laxa* was present on a few, either alone or accompanied by *S. fructigena*, while *Botrytis cinerea* and a species of *Mucor* were also found on some of them.

A sample from each of three other batches of Victoria and one of Giant Prune was examined in the same way and with very similar results, as shown in the table. In these batches the fruit had been stored for from 12 to 19 days, and it was evident that considerable wastage may occur within such a short period.

The records were continued on two samples of Bradley's King damsons which had been stored for 31 and 34 days respectively. When taken out of store many bore a dense white mould with no fructifications. In some instances the rot had started at one fruit as a centre and spread by contact to those around so that the rotting fruit were often adhering in clusters of from two to eighteen, a condition characteristic of brown rot mummies on the tree. In most of these, where it could be traced, it was found that the rot had started at an unstalked fruit and spread to one adjacent. Many pairs, each of a stalked and an unstalked fruit, were seen, and from the degree of infection in such pairs it was evident that the rot had started in the unstalked fruit. Of the clusters examined, four bore *S. fructigena*, eleven *S. laxa* and three had both fungi. In one of the samples *S. laxa* was the predominating fungus while in the other it was *S. fructigena* ; taking the two samples together *S. fructigena* was found on 123 and *S. laxa* on 109 damsons, so it would seem that, on the Bradley's King damson, the two species of Brown Rot fungi are about equally active in producing rot in storage, in contrast to the varieties Victoria and Giant Prune in which the plums infected with *S. fructigena* were far more numerous than those with *S. laxa*.

The rot had developed to a greater degree on Bradley's King than on Victorias and Giant Prune, as shown by the amount of fungal mycelium, the clusters of rotting damsons and the shrivelling of the infected fruit. This was due, in part at any rate, to the longer period during which they had been stored. When exposed to light, therefore, the infected damsons showed a tendency to dry up and become mummied rather than to produce fructifications, so that in many of them it was impossible to determine which fungus was present. It was obvious, however, that almost all the rot was due to one or other of the two brown rot fungi as shown by the numbers obtained of those damsons on which the fungi developed sufficient fructifications for identification.

The results confirm those obtained in 1934—that the wastage in plums in cold storage is caused chiefly by the Brown Rot fungi, particularly *Sclerotinia fructigena*.

To avoid such wastage attention should be directed towards :

(1) Orchard sanitation, to prevent severe outbreaks of Brown Rot on the tree, by removing and burning, so far as practicable, rotting and mummied fruit.

(2) Careful picking and storing to obviate bruising the fruit. Plums picked with stalks keep better than the stalkless fruit.

(3) Removal, before the fruit is stored, of any plums showing even a trace of rotting.

(4) The use of clean baskets and trays, which have not come in contact with rotting fruit ; if the baskets or trays are not scrupulously clean they should be soaked in formalin solution 1 : 320 and allowed to dry before they are used for storing fruit.

A further article dealing with some other aspects of storage such as the relation of wastage to maturity, length of storage, temperature, etc., will be found on p. 288 of this Report.

TABLE SHOWING THE NUMBER OF FRUIT INFECTED WITH VARIOUS FUNGI IN SAMPLES OF ROTTING PLUMS TAKEN FROM COLD STORAGE.

Variety of Plum.	Victoria.				Giant Prune.	Bradley's King.	
Date when stored	Aug. 29	Sept. 1	Aug. 31	Aug. 29	Sept. 12	Sept. 1	Sept. 1
Date when removed from store	Sept. 10	Sept. 15	Sept. 16	Sept. 17	Sept. 28	Oct. 2	Oct. 5
Percentage rejected as over-rip	1·2	1·5	1·4	3·6	10·9	4·4	2·6
Percentage showing fungal rot	2·3	2·5	1·3	3·0	3·3	8·8	14·1
Sclerotinia fructigena	81	87	48	67	135	46	66
S. laxa	8	29	7	26	6	57	44
S. fructigena + *S. laxa*	3	7	—	8	—	—	5
,, + *Botrytis*	2	6	4	6	1	1	—
,, + *Mucor*	7	2	1	1	—	—	—
,, + *Penicillium*	—	—	—	—	—	3	2
,, + *Botrytis* + *Mucor*	—	—	—	1	—	—	—
,, + *Botrytis* + *Penicillium*	—	—	—	1	—	—	—
S. laxa + *Botrytis*	—	—	1	3	1	1	2
,, + *Mucor*	—	—	2	2	—	—	—
,, + *Penicillium*	—	1	1	—	—	—	—
,, + *Botrytis* + *Penicillium*	—	—	—	1	—	—	—
No. with Brown Rot	101	132	64	116	143	108	119
Botrytis	4	12	21	10	6	3	1
Mucor	4	2	8	8	7	1	—
Penicillium	—	—	10	—	—	2	2
Botrytis + *Mucor*	1	—	—	3	—	—	—
,, + *Penicillium*	—	1	3	—	—	1	—
Mucor + *Penicillium*	—	1	3	1	—	—	—
No. not showing Brown Rot	9	16	45	22	13	7	3
Percentage with one or other of the Brown Rot fungi	90·9	94·3	58·7	84·1	91·7	93·9	97·5

SUMMARY.

An account is given of further observations on the wastage, by fungi, of plums in cold storage.

Under storage conditions there is a tendency for the fungal fructifications to be suppressed, so the fungi were identified by inducing them to produce fructifications by exposing the fruit to light.

In this way it was found that most of the wastage is due to infection by the Brown Rot fungi, *Sclerotinia fructigena* and *S. laxa*, particularly the former.

To avoid excessive wastage the recommendations are sanitary measures in the plantation, careful picking and storing, and the use of clean, or uncontaminated, baskets and trays when storing the fruit.

Bradley s King Damson with *Sclerotinia laxa*, from cold store

VIRUS DISEASES IN RELATION TO STRAWBERRY CULTIVATION IN GREAT BRITAIN—A SYNOPSIS OF RECENT EXPERIMENTS AT EAST MALLING*

By R. V. HARRIS

I. Introductory and Historical.

The origin of the cultivated strawberry varieties is of considerable relevance to the subject under review. Experts are mainly agreed that their common progenitors in Europe are two American species, *Fragaria chiloensis* Linn., a native of the coastal mountain ranges of western South and North America, and *Fragaria virginiana*, a small-fruited woodland species common in eastern North America, and still commercially cultivated under the name of Scarlet or Little Scarlet. These species were imported to Europe in the early eighteenth century and, as Mr. Bunyard has felicitously said (3) : " The wedding ceremony of the American immigrants was celebrated in England." From European countries certain varieties from this phenomenal hybridization found their way back to America, whence by further crosses with *F. virginiana* issued the cultivated North American varieties. Hedrick (6) referring to the extensive collection of both North American and European cultivated varieties at the New York State Agricultural Experiment Station (Geneva, N.Y.) remarks that, " The veriest tyro in strawberry study can detect the characters of *F. chiloensis* and *F. virginiana* in these seedlings " and that " the characters of one species predominate here ; those of another there ".

Mr. Bunyard in his elegant treatise (3) goes on to lament that " Of the great number of varieties which were raised during the past century some still remain in the first rank to-day, but too many varieties have not this fixed and resting quality and come into prominence and fade away before they are hardly known." He then reviews varieties of tried gustatory merit, among which *Dr. Hogg*, " one of the best flavoured of all strawberries, and would it but grow it would be found in every garden. Its inveterate habit of *becoming beautifully less*† will daunt all but the most determined epicure." Many causes have been suggested to account for this bad habit but the fact remains that continued success in commercial strawberry growing whether under glass or in the open plantations is still an accomplishment by no means common among growers. In explanation the successful grower generally emphasizes one or more of the following contributory factors : (*a*) a good variety ; (*b*) a good " strain " of that variety, obtained by drastic selection and elimination of the unfit ; (*c*) adequate mite and insect control, and (*d*) a suitable soil, well drained and manured.

It is the purpose of the present essay to outline recent investigations at East Malling indicating that virus disease is a serious and widespread contributory cause of varietal deterioration in this country. Each of the above points upon which the successful grower places emphasis will, further, be shown to have an immediate bearing on the control of such disease.

* Reprinted from the Scientific Journal of the Royal College of Science, Vol. VII, by permission of the Joint Publication Board.

† Our italics.

In 1927 a cropping trial of three " strains " of the leading present-day variety Royal Sovereign, previously collected from well-known sources, was planted at East Malling on statistical lines (13). Considerable variation in performance from plant to plant and from strain to strain was observed on this plot, in spite of the uniform soil conditions obtaining, and a process of individual plant selection and propagation was started in 1928 with the object of obtaining a uniformly vigorous race of plants for experimental purposes.

The first cause of variation on this trial plot to be determined was the Tarsonemid Mite (*Tarsonemus pallidus* Bks.), which was subsequently shown by Massee to be an extremely potent direct cause of plant deterioration in Royal Sovereign under certain seasonal conditions (7). Massee further found that " some plantations may partially recover after being severely infested and damaged by mites. In other badly mite-infested plantations the plants fail to recover and, in practice, the plants have been ploughed up " (1). This frequent non-recovery of " mite-plants " suggested the incidence of a further pathogen, but repeated examinations of suspected plants, however, failed to reveal such.

In the autumn of 1930 Mr. W. Corbett, advisory officer in glasshouse crops to the Kent County Council, drew our attention to symptoms on plants of the same variety, grown in pots for forcing, in the Swanley district, and indicated the similarity of these symptoms to descriptions of those of a recently identified virus disease in California known as Yellows or Xanthosis (4, 12). Similar symptoms were subsequently identified on plants in the trial plantations at the Research Station and transmission experiments by runner-grafting carried out in 1931 and 1932 indicated conclusively the virus origin of this disease to which the descriptive name of Yellow-edge was given (5). Considerable advance was made in 1934 when Massee showed the common strawberry aphis to be a vector of this disease (9).

In the seasons of 1933 to 1935 during and following a period of residence in Eastern Canada, the writer and his Canadian collaborator, Dr. A. A. Hildebrand,* using the Royal Sovereign variety as indicator, compared Yellow-edge with the disease analogous to Xanthosis in eastern Canada. The results of these experiments provided evidence supporting the identical nature of the diseases in each country. The Canadian varieties used in the experiments were further shown to react to the disease in a manner distinct from that of Royal Sovereign and approximating to that of a " symptomless carrier ", and further experiments carried out with other English commercial varieties at East Malling in 1935 provided additional information on this point.†

In the spring of 1934 Ogilvie, Swarbrick and Thompson of the Long Ashton Horticultural Research Station, Bristol (11), published a description of severe symptoms observed by them on Royal Sovereign plants in the south-western counties, and stated by them to be distinct from those of " Aphis-plant " (2) and the similar symptoms of Yellow-edge, and to resemble those of the " Crinkle " virus disease in North-West America (15).

In the autumn of the same year similar (" Crinkle ") symptoms were observed at East Malling on recently introduced plants of certain seedling varieties (from crosses of English with American varieties), but appeared to be absent from neighbouring Royal Sovereign plantations. In the following year transmissions (by grafting) were successfully carried out from type " Crinkle " material supplied by the Long Ashton workers, to " normal " Royal Sovereign plants and the common identity and virus

* Of the Dominion Laboratory of Plant Pathology, St. Catherines, Ontario.

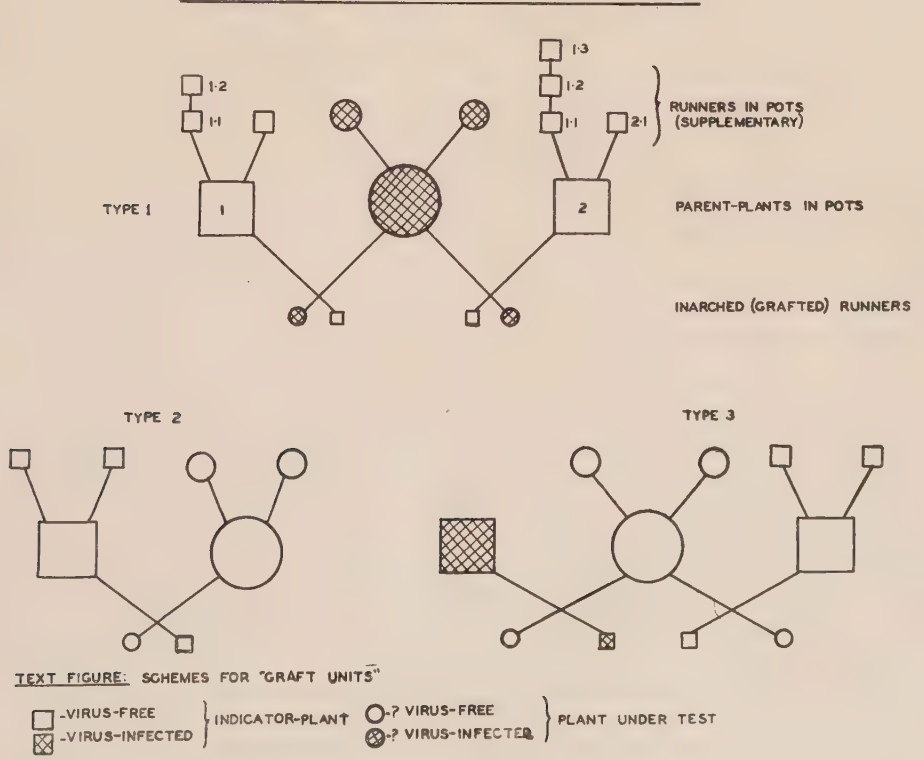
† A detailed account of this investigation will shortly be published.

origin of the diseases at East Malling and in south-western England was thereby established. Further experiments in 1935 and 1936 finally established the existence of two causally distinct but closely associated types of virus disease (Yellow-edge and " Crinkle ") in strawberry plants at East Malling, and the wide distribution of the latter in a " mild " form throughout the specially selected and " virus-rogued " clonal race of Royal Sovereign plants at the Research Station, and in other commercial varieties.

The remainder of this paper will consist of a summary of the recent observations and experiments on these two virus disease types at East Malling.

II. Methods of Determination.

Owing to the drastic symptoms ascribed directly to infestation by aphis (2) and mite (7) it became necessary at the start to determine a mode of transmission independent of the use of possible insect vectors. Grafting by various methods was, therefore, attempted in 1931 (4) and a convenient method of stolon-grafting or " inarching " was eventually chosen which could be rapidly and easily carried through and relied on to yield a high proportion of successes on the open greenhouse bench or in the plantation.



By this method any number of plants and their runner-systems can be organically united in series. The passage of the virus (as evidenced by symptom transmission) into a " normal " plant and throughout its runner-system was found to be so rapid that in the later experiments the grafted-stolons with their runner-plants were discarded after transmission had been effected, and transmitted symptoms were read on other or

"supplementary" runner-plants struck into pots for the purpose. The text figure shows the plans of the various types of graft combination (or "graft-units") used in the recent experiments. Type 1 units are used for determining the transmissibility of suspected symptoms. Types 2 and 3 units are complementary and are used to test the reaction of *apparently* "normal" plants of a variety to a given disease; the type 2 unit indicates any prior infection of the plants under test, and in type 3 units the plant is infected from a given source, a "normal" indicator being grafted in series in case the variety should react as a "symptomless carrier".

The "indicators" used in the East Malling and Canadian experiments up to the close of the 1935 season were derived from a clonal race of Royal Sovereign plants originating from a single plant of the original "strain-trial", selected in 1928 and subjected to continual re-selection on qualities of general health and vigour, and latterly to "roguing" for virus symptoms. In 1936 the common woodland strawberry (*F. vesca*) was first used as an indicator.

III. Yellow-edge.

A. Symptoms and Susceptibility of Royal Sovereign. (See Plate.)

The distinctive leaf-symptoms of this disease as induced on the "normal" Royal Sovereign indicators in the initial 1931 and 1932 experiments are:

(*a*) a chlorosis (or yellow coloration) localized in the marginal region;
(*b*) a downward and upward cupping of leaflets;
(*c*) a dwarfing of the laminae and stunting of the petioles.

Symptoms (*b*) and (*c*) are, of course, consequent on (*a*), and as the degree of chlorosis varies on different leaflets of the same leaf and on different portions of the same leaflet, the intensity of the cupping also varies from leaflet to leaflet, giving the yellow-edge leaves their characteristic asymmetrical appearance. The stunting of the petioles, if pronounced, gives the affected plant a characteristically flattened appearance.

These symptoms not only vary greatly in intensity from plant to plant in the same plantation, but are not produced continuously throughout the growing season except in advanced cases and under exceptional seasonal conditions. This intermittent expression of symptoms or tendency for symptom-masking is highly characteristic of the disease and adds considerable complication to the problem of control. It varies greatly in different varieties and also depends on other and environmental factors which will be enumerated in the discussion on control measures (see Section V). Generally speaking, Royal Sovereign is highly susceptible to deterioration by this disease. In certain cases the attack may be so mild that a plant and its infected runner-progeny may retain their vigour for a considerable time; in a high proportion of cases, however, the infected plant and its progeny rapidly deteriorate in vigour, crop, and runner production, and a completely "flat" sterile condition is reached, sometimes during the season in which the infection occurs. Plants are not directly killed by the disease.

That infection often results in serious reduction in crop is shown in the table.* The data summarized in this table were derived from a plot planted with a clone of normal Royal Sovereign plants, the detailed individual histories of which were available, and, in order to reduce the plant to plant variability factor for the purposes of the comparison, the fourteen normal plants and fourteen Yellow-edge plants were selected in pairs, each

* The writer is indebted to Mr. W. S. Rogers for the compilation of this table.

THE EFFECTS OF YELLOW-EDGE VIRUS ON ROYAL SOVEREIGN

Note.—The figures are the average of 14 comparable plants in each case.

	Healthy Plants.	Plants showing Yellow-edge in 1933.
Weight at planting, October, 1931 (gm.)	5·3	5·7
Diameter, May, 1932 (inches)	4·5	4·5
Blossom figure, May, 1932	1·4	1·6
Diameter, September, 1932 (inches)	15·9	15·9
Diameter, May, 1933 (inches)	18·9	15·0
Height, May, 1933 (inches)	10·8	7·5
Fruit, June, 1933. Number	71	57
Weight (gm.)	381	289
Average weight per fruit (gm.) ..	5·4	5·1
Equivalent crop per acre (cwt.)	72·5	55·0

pair being exactly comparable in origin (i.e. from the same (normal) parent plant and of the same age, order, etc.).

B. Relative Varietal Susceptibility.

Following the discovery in 1933-4 of certain Canadian varieties with a capacity for symptom masking greatly in advance of Royal Sovereign, similar experiments (1) with certain relevant species of *Fragaria* and (2) with Royal Sovereign and four additional leading English cultivated varieties, were made at East Malling in 1935, using exactly comparable " normal " Royal Sovereign plants as indicators and a uniform set of clonal Yellow-edge plants of the same variety as the source of infection. Type 2 and type 3 graft-units (see text figure) were set up using plants of each species and variety carefully selected (over several seasons) for freedom from Yellow-edge symptoms. The results are briefly summarized below.

1. *The Parent Fragaria Species.* These showed sharply contrasted reactions to the disease. *F. chiloensis* was found to combine high resistance to deterioration with an extremely high capacity for symptom masking. All the plants selected for the experiment (as apparently normal) proved to be Yellow-edge infected, but no trace of leaf symptoms were detected until the late winter of the present year (1937), when a faint marginal chlorosis was noted on a few of the leaves of some of the plants. This species can therefore be regarded as a virtual symptomless-carrier with high resistance and possibly immune. *F. virginiana* on the other hand proved to be very highly susceptible to deterioration and exhibited all symptoms distinctly throughout the experiment.

2. *Cultivated Varieties.* These formed a series between the extreme reactions of the parent species, from the Lefebvre variety which combined a high resistance (but not immunity) with a low capacity for symptom masking (only slightly below that of *F. chiloensis*) to Sir Joseph Paxton and Royal Sovereign with high susceptibility to deterioration and low capacity for symptom masking.

To sum up, it will be noted that no variety has yet been found that combines distinct leaf-symptom expression (low masking capacity) and high resistance to deterioration ; the symptoms are readily masked on such varieties. These " resistant " varieties (even *F. chiloensis*), however, ultimately exhibited slight leaf-symptoms, and all of

them (with the possible but improbable exception of *F. chiloensis*) gave indications of some small degree of susceptibility to deterioration under the conditions of the experiments. Concurrent and subsequent field observations confirm the implications of these results, namely that the degree of susceptibility of varieties to the deteriorating action of the Yellow-edge disease varies inversely with their capacity for leaf symptom masking, i.e. the greater the resistance to Yellow-edge the greater the difficulty in identifying infected plants.

Finally it must be noted that although varieties and species are readily classifiable according to their relative susceptibility, there is also within each variety a wide range of susceptibilities and symptom-expressing propensities from plant to plant. This has already been noted in the case of Royal Sovereign and is clearly due in large extent to environmental factors which will be discussed in the following section on control measures. Such, however, does not appear to be the whole explanation of this individual plant variation, and certain results of recent experiments require the assumption of the existence of distinct strains of the virus causing the Yellow-edge disease, some more virulent than others. Multiple strains are not unknown in virus diseases of other crops and would provide a ready explanation, for instance, of *apparent* differences in susceptibility to Yellow-edge infection (based on the relative proportion of plants showing leaf-symptoms) previously recorded between "strains" of Royal Sovereign collected from different sources and brought together on to a single trial plot. If differing strains of Yellow-edge were dominant in each of the original collections of plants such would tend to persist for some time after all the collections were brought under the same environmental conditions and that collection (or Royal Sovereign " strain ") in which the milder strains of Yellow-edge (with higher symptom masking capacity) were predominant, would, under a given set of conditions, tend to show a higher proportion of *apparently* " normal " plants. In further support of this supposition it is interesting to note that between new clonal races built up by individual plant selections and re-selections from the Royal Sovereign " strains " in question no such differences in apparent susceptibility to Yellow-edge infection have been shown by the records.

IV. Crinkle Disease. (See Plate.)

Reference has already been made above to the original record of " Crinkle " symptoms on Royal Sovereign in south-west England by Ogilvie, Swarbrick and Thompson in 1934 (11) and of the subsequent confirmation of their virus origin by runner-grafting transmission to normal Royal Sovereign plants in 1935 at East Malling. In the latter experiments, however, characteristic Yellow-edge symptoms appeared at a later stage on the leaves of the indicator plants of the type 1 graft-units, in addition to the induced severe Crinkle symptoms, so that it was actually on the basis of certain results from an experiment in the series with the common woodland strawberry *F. vesca*, that the distinct causal origins of Crinkle and Yellow-edge were established and that the basic facts relevant to the incidence of the former in the East Malling locality became apparent.

A. Fragaria vesca as an Indicator of " Crinkle " and Yellow-edge.

Owing to the prevalence of wild strawberry (*F. vesca*) in the woods abutting on the Research Station runner-beds a series of type 2 and 3 graft-units were set up in 1935 to test its susceptibility, using Royal Sovereign as the " normal " indicator and also the source of the Yellow-edge. The reaction of the *F. vesca* plants to the disease (in the type 3 units) was severe with the production of distinct symptoms of the Yellow-edge

type. In addition, however, it was noticed that the leaves of the infected plants became blistered or wrinkled. On the other hand the normal plants grafted on to the " normal " Royal Sovereign indicators in the type 2 units developed the wrinkling symptoms alone suggesting that both the " normal " and Yellow-edge Royal Sovereign plants were infected with a disease distinct from Yellow-edge. Subsequent close examination showed that the minute spot-lesions characterizing the Crinkle disease were actually present in small numbers on most of the " normal " and Yellow-edge Royal Sovereign plants, the symptoms commonly being limited to a small group of spots at the base of a leaflet or two, and only detectable with difficulty. These results were amply confirmed in 1936 by a large-scale experiment on the use of *F. vesca* as an indicator and, in brief, show that the Crinkle disease is widely distributed, mainly in this extremely " mild " form, throughout the available stock of healthy (Yellow-edge free) Royal Sovereign plants and that this disease is also constantly associated with Yellow-edge; i.e. all Yellow-edge plants recently examined show additional minute indications of mild Crinkle infection. A further point in favour of the distinct nature of Crinkle and Yellow-edge is the apparent antagonism between the two diseases in association; i.e. severe Yellow-edge symptoms are generally combined with mild Crinkle symptoms and vice versa.

B. Mild and Severe Crinkle.

During the 1935 and 1936 season a small but increasing number of cases of " severe " Crinkle, similar to those described in south-west England (11), were observed on Royal Sovereign. Certain results of experiments during these seasons, however, indicate that there is a causal distinction between the mild (and widely distributed) phase and the rarer " severe " phase, i.e. that the latter phase is induced by an additional infection of mild Crinkle plants with a further pathogen (virus).

C. Symptoms.

The basic distinction between the symptoms of Crinkle and Yellow-edge is in the distribution of the chloroses. In the case of Crinkle the chlorosis is discontinuous, being localized in minute circular areas or spots scattered unevenly, and in varying concentration over the leaf lamina. On Yellow-edge leaves the chlorosis is continuous around the marginal region. The crinkling of the former and the cupping of the latter leaves are the natural consequences of the check to leaf growth resulting from these two modes of chlorosis and its intensity depends on the relative proportion of the leaf area thus affected.

V. Insect Vectors.

Briton Jones and Staniland (2) were the first workers to carry out controlled infection experiments with the common strawberry aphis (*Capitophorus fragaefolii* Col.) in this country, from which they concluded it to be a pest of widespread and critical importance to the strawberry grower. Although, however, these workers considered this insect as a potential virus vector they regarded the injury caused by it to be largely of a direct nature.

In 1934 Massee (9) showed by a controlled artificial infection experiment carried out on the open ground that this aphid is a vector of Yellow-edge. This result was confirmed by a further trial in 1935 (10), when successful transmissions by this means were made throughout May, June and July, symptoms being recorded seven weeks after inoculation.

In 1936 the period of potential infection was shown to extend from March to September inclusive.

In view of the fact that the American Strawberry Aphid has been shown to be a vector of the Xanthosis disease (the analogue of Yellow-edge in America) it is interesting to note that (10) " The Delicate Strawberry Aphid (*Capitophorus fragariae* Theo.) and the American Strawberry Aphid (*Myzus fragaefolii* Cockll.) are considered to be identical, and the correct name of the species is considered to be *Capitophorus fragaefolii* Col." It is also of interest that the same aphis has been proved to be a vector of " Crinkle " in north-west America (14). The close association of the two analogous diseases in England suggests that here, too, they may be transmitted by a common vector and experiments are being planned to test this point.

As an integral part of both the above experiments Massee also attempted to transmit Yellow-edge by means of the Tarsonemid Mite, *Tarsonemus pallidus* Bks., but with completely negative results. The urgent necessity for the elimination of mite from runner-beds, however, must be emphasized, on account of the serious masking of virus symptoms resulting from infestations.

VI. Control Measures.

A. The Maintenance of Reliable Supplies of " Virus-free " Runners.

The rapid systemic dissemination of the Yellow-edge virus throughout the runner system of an infected plant has been amply proved by observation and experiment. Thus a single natural infection (by aphis or otherwise) in a runner-bed may result in the production of anything from 20 to 150 new potential sources of infection. It is easy to see, therefore, that unless a system is adopted for eliminating such infected plants from the runner-bed the entire available stock of a variety must ultimately become infected. The rate at which such a variety becomes " beautifully less " will thenceforward largely depend on the degree of susceptibility of that variety to the action of the virus, but the fact that an immune variety has not yet been found implies that even the " resistant " varieties must eventually disappear unless control measures are applied.*

It has already been pointed out that the selection and propagation of clonal races of Royal Sovereign was started at an early stage in the investigation of this variety at East Malling. In 1932, following the identification of Yellow-edge, routine inspections and " roguings " for this disease were commenced on runner-beds specially designed to facilitate the ready elimination of infected plants and all their runner progeny. The efficacy of this system for maintaining supplies of Yellow-edge free runners clearly depended on the relation between infection and the appearance of clearly visible diagnostic symptoms. Experiments already described have shown that Royal Sovereign combines high susceptibility with a low capacity for symptom masking. Even so these symptoms become masked at times and such masking has been shown by field experiments started in 1935 to be related to the interaction of the following environmental factors :

(i) Seasonal and weather conditions ;
(ii) The age of the infected plant ;
(iii) Soil conditions.

(i) In a uniform population of uniformly infected plants a proportion of the plants will generally show symptoms in early summer (June). This is usually followed by a

* The writer is satisfied that the outstanding success of certain growers in maintaining the vigour of their " strains " of such susceptibles as Royal Sovereign has depended to a large extent on their intuitive elimination of virus plants from their runner-beds.

general masking of symptoms and the highest proportion of infections become detectable in the autumn (from mid-September until the plants stop growing). This " seasonal-cycle " has been shown to be related to temperature and moisture conditions. Symptom expression in Yellow-edge is encouraged by cool-moist weather, and symptoms are masked in hot dry weather. Active plant growth is also a necessary condition for symptoms to show and such rapidly fade away when growth ceases. For these reasons a preliminary " roguing " of runner-beds should be carried out in June, and the final critical inspections and roguing in September and October. It must be borne in mind, however, that in exceptionally dry hot seasons only a low percentage of infected plants may show symptoms at any time so that the system of control by the " roguing " of runner-beds largely depends for its effectiveness on an unbroken sequence of annual inspections.

(ii) Experiments have recently shown that under uniform seasonal conditions infected maiden plants are less likely to develop symptoms than comparable two-year-old infected plants. Thus inspections and " roguings " are likely to be more effective on a two-year-old runner-bed than on a maiden runner-bed.

(iii) Similarly, comparable infected plants have been found more liable to develop symptoms on soils producing poor growth than on soils encouraging luxuriant growth and runner production. The existence of multiple strains of the Yellow-edge virus and their relation to variant symptom-expression has already been noted.

The experiments in runner production culminated in the establishment of further experimental " runner-nurseries " at selected outside centres, which have given highly satisfactory results where adequate isolation from infected plantations has been provided, and with an issue to the industry in 1936-7 from the Research Station runner-beds of large consignments of *clonal* uniformly vigorous and healthy Royal Sovereign runner plants. Random samples from this race of runners tested by means of *F. vesca* indicators in 1936 were found to contain a negligible proportion of Yellow-edge infections.

B. The Elimination of " Carrier " varieties and Breeding for Resistance.

It does not follow that the above system of control will be applicable to other and less susceptible varieties, for it has already been seen that greater resistance is coupled with a greater tendency for symptom masking. Thus a heavily infected bed of Lefebvre may appear free from Yellow-edge symptoms at a time when a similarly infected Royal Sovereign bed shows a high percentage of Yellow-edge plants. Unless, therefore, such resistant " carriers " are immune, their complete deterioration is eventually inevitable because an adequate elimination of virus-plants on the basis of visual inspection is impracticable. It has further been seen that, to date, all " resistant " cultivated varieties observed have yielded evidence that they are not immune. Meanwhile such varieties (being of the " carrier " type) are in all probability a potent source of infection for " susceptibles " such as Royal Sovereign and should, as far as possible, be eliminated or isolated where these varieties are propagated or cropped.

The " resistant " varieties so far produced by recent breeding work approximate to *F. chiloensis* in their reaction to Yellow-edge ; i.e. that of a resistant " symptomless-carrier ". As has already been seen, immunity to virus-deterioration must be attained if such varieties are to be of lasting use. A valuable alternative to this, but not yet discovered is the highly susceptible variety with low infectibility, i.e. a variety which only rarely becomes infected, but which exhibits symptoms distinctly so that infected plants can be eliminated without delay. It is interesting that under East Malling

conditions cases of natural infection of the highly Yellow-edge susceptible *F. vesca* have not been observed. Massee also reports that aphis infestations have not yet been observed on this species under local woodland conditions.

C. Adequate Aphis and Mite Control.

The need for Aphis control is self-evident. The method at present recommended (spraying with nicotine and soft soap) aims at destroying the insects already on the plants. To check virus spread, however, control measures which will also deter the aphids from the plants, or otherwise protect plants from primary infestation is needed, and experiments to determine such are in progress.

The serious masking of Yellow-edge symptoms by mite makes the adequate control of such by the warm water treatment of planting material (8), and isolation* from infested centres essential.

D. Optimum Soil Conditions.

It has already been pointed out that where a plant is infected with a mild form of Yellow-edge the rate of deterioration has been seen to vary according to local soil conditions. For runner-beds a poorer soil has been shown to be a possible advantage, but in the case of fruiting plantations planted originally with " virus free " runners, it may well be that the deleterious effects of natural infections can be reduced by adequate soil treatments.

And so, in conclusion, we return to the growers' " points " enumerated at the outset and see that each has a direct bearing on this problem of virus control.

Thus (*a*) choose those varieties from which virus-plants can be easily eliminated ; (*b*) secure a supply of runners from a race (strain) of that variety selected and propagated to maintain adequate freedom from the important virus diseases ; (*c*) eliminate insect vectors as far as possible and take measures to prevent the masking of virus symptoms on runner-beds by mite ; (*d*) discourage symptom masking on runner-beds, and plant deterioration on fruiting plantations by the provision of suitable soil conditions.

Acknowledgments are due to the writer's colleagues, Dr. A. M. Massee and Mr. W. S. Rogers, for assistance and encouragement in compiling this summary which embodies, also, their own considerable contributions to the investigation.

Summary.

An outline is given of observations and experiments on strawberry virus diseases carried out at East Malling from 1931 to 1936 inclusive, together with a summary of conclusions, with special reference to field diagnosis and control measures.

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* Minimum of 30 yards from other strawberry plantations and with intervening hedge or trees.

FIG. 2.

The symptoms of Yellow-edge (upper plant) and of Severe Crinkle (lower plant). Comparable maiden plants of Royal Sovereign variety contemporaneously infected by "runner-grafting" in 1935. Photo. 10th September, 1936.

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STUDIES IN STRAWBERRY VIRUS DISEASES

III. TRANSMISSION EXPERIMENTS WITH "CRINKLE", 1935

By R. V. HARRIS

I. General Introduction.

In 1934 Ogilvie, Swarbrick and Thompson (4) described symptoms observed by them on seriously diseased plants of the Royal Sovereign variety in Worcestershire and other districts in South-West England stating them to be distinct from those of Aphis-plant (1) and Yellow-edge (3) and identical with those of the "Crinkle" disease prevalent in the North-Western States of America. The latter disease was identified by Zeller and Vaughan (5, 6, 7) who later showed it to be of virus origin and transmitted by the common aphis *Myzus* (*Capitophorus*) *fragaefolii*.

In the spring of 1934 a collection of seedling varieties raised by Mr. Daniel Boyes of the School of Agriculture, Cambridge, was planted at East Malling for observation and trial. This consisted of from 5 to 10 plants from each of a selection of F 1 generation seedlings derived from crosses between leading English varieties and certain North American varieties selected for qualities of hardiness and vigour. In the following autumn the present writer assisted in a plant to plant disease survey of this collection, when seven of the families were recorded as showing symptoms closely resembling those of "Crinkle" in North America, and the analogous disease on Royal Sovereign in South-West England described by the Long Ashton workers.

Hitherto symptoms of this type and intensity had not been observed at East Malling on Royal Sovereign or any other variety* and in view of the proximity of experimental plantations and "runner nurseries" of such varieties to the suspected seedlings it became immediately necessary to determine the cause of the "Crinkle", its relation to Yellow-edge and the reaction of the disease on the Royal Sovereign variety under local conditions. Transmissions to normal Royal Sovereign plants from selected plants of the seedling varieties in question were therefore attempted in 1935. At the same time a joint experiment was planned for the same year with the Long Ashton Horticultural Research Station, Bristol, to compare the reactions of Royal Sovereign to Yellow-edge and "Crinkle" under the contrasted growing conditions at the two Stations by infecting uniform batches of "normal" Royal Sovereign maiden plants (of clonal origin) at each centre simultaneously. For this purpose the Long Ashton collaborators supplied a number of plants of a single seedling variety known to be "Crinkle" infected, and attempts were made to transmit the disease from these to Royal Sovereign plants, as a preliminary to the proposed joint trial.

Both the above transmission experiments yielded positive results and are the subject of the present communication.

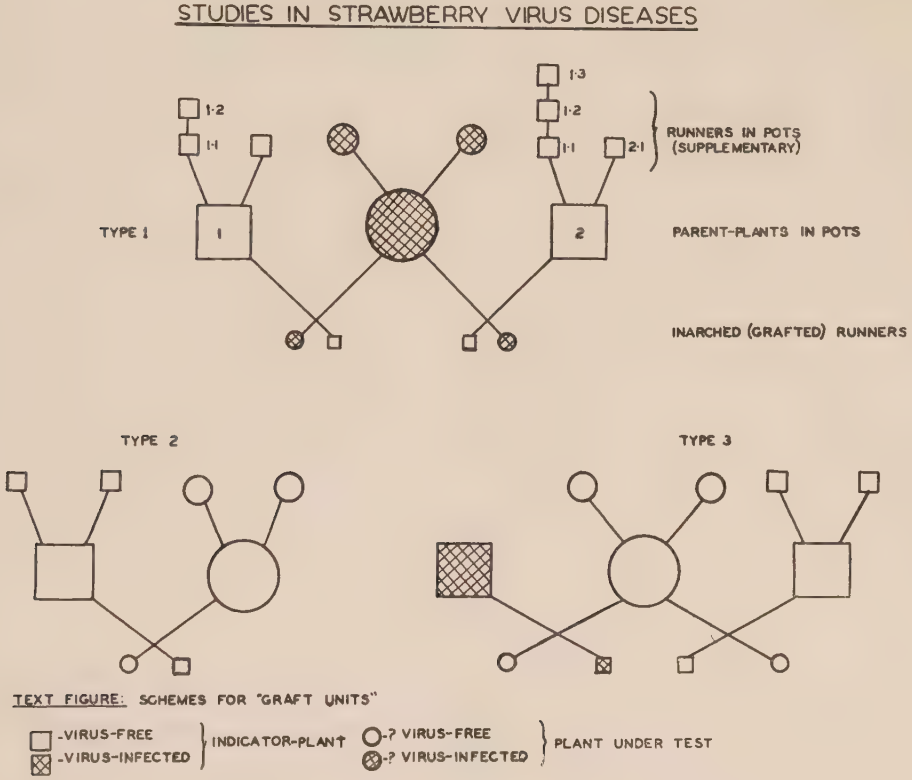
II. Method.

The two experiments under consideration were planned as part of a series carried out in 1935 in continuation of the initial experiment in 1932 when symptoms of the

* This does not preclude the possibility that isolated cases may have previously occurred, particularly in view of a resemblance of the symptoms in question to those due to direct injury by certain insects. There can be no question, however, but that such were of rare occurrence.

Yellow-edge type were first transmitted to " normal " Royal Sovereign plants (3). The method used was substantially the same (2), namely runner-grafting (or inarching) with certain modifications in detail which will be described in a further publication dealing with the other experiments of the same series.

The types of graft-combination or " Graft-units " used throughout are illustrated in the text figure. In view of the rapid transmission of virus which took place in the



earlier experiments from the grafted stolons into the parent " indicator plant " and on into other and ungrafted runners, the three types of unit were planned to simplify manipulation after grafting by striking into pots " supplementary " or non-grafted runners in place of the grafted runners themselves, the latter being merely used for the purpose of transmission and discarded after this had been achieved.

The " Indicator plants " were drawn from a uniform supply of " maiden " Royal Sovereign plants in pots derived from " virus-rogued " runner-beds of the same clonal race supplying the material for the previous experiments.

III. Control Units.

In the absence of comparable " normal " plants of the seedling varieties under test, " controls " were eight type 2 units, set up with " normal " plants of Royal Sovereign and four other commercial varieties at the same time as the " Crinkle " units.

The records on these control units will be discussed in detail in a forthcoming publication dealing with the results of the other experiments with which they were

immediately associated. Here it may simply be stated that no symptoms of the "Crinkle" type comparable to those recorded on the Indicator plants of the units under consideration were recorded on these control-units.

IV. The Cambridge Seedlings.

A. Survey of Symptoms.

This collection which was planted on a trial plot at the Research Station in the spring of 1934 comprised 5 to 10 plants of 49 seedlings (F 1 generation) from crosses of Royal Sovereign, Sir Joseph Paxton, and Tardive de Leopold with selected North American varieties.

The families were planted out seriatim in rows which, where necessary, were completed with plantings of comparable "Clonal" normal Royal Sovereign plants (twenty-three in all) from the same source as the indicators in the transmission experiments.

On 21st November, 1934, definite cases of Yellow-edge were found in fifteen of the forty-nine families; in seven families, however, severe symptoms of a type quite distinct from Yellow-edge were recorded, namely a distortion or "crinkling" of leaves to a varying degree, associated with small circular to irregularly shaped chlorotic spot-lesions (with or without necrotic central portions) present in varying concentration and suggesting at first glance direct injury by some insect such as capsid-bug. In five of the families thus affected the "Crinkle" symptoms were combined with the chlorotic leaf-margins and leaf-curling characterizing Yellow-edge, although the former symptoms were so markedly dominant that the latter could only be identified with difficulty; in the remaining two families the "Crinkle" appeared to be uncomplicated by Yellow-edge (see Table I).

Table I.

Cambridge Seedlings.

Analysis of Families with Suspected "Crinkle", November, 1934.

Index No.	Parentage.	Total plants alive.	Plants normal.	"Crinkle" + Yellow-edge.	"Crinkle."
30/14/32	Tardive × Ettersburg Seedling 121	5	—	5*	—
30/14/27	,,	5	—	5	—
30/16/9	Tardive × Ettersburg Seedling 80	5	—	—	5*
30/16/10	,,	5	2	1*	1*
30/16/18	,,	5	4	1	—
30/16/26	,,	5	2	—	1
30/17/19	Tardive × William Belt	10	5	—	4*

* Transferred to Greenhouse in spring 1935.

At the same time none of the twenty-three Royal Sovereign plants on the plot showed "Crinkle"; five were dead, eight showed definite Yellow-edge and ten were "normal" and vigorous.

On account of the striking similarity of the above "Crinkle" symptoms and those previously noted by the Long Ashton observers on Royal Sovereign in South-West England, all suspected plants were "rogued" from the plot in the early spring of 1935 and a selection removed to the greenhouse for use in the transmission experiments.

B. The Experiment.

1. *Lay-out.*

On 22nd and 24th June two type 1 graft units (see Text figure) were set up. As the source of " Crinkle " suitable runner-producing plants from the two families which up to this time had shown " Crinkle " only were selected, and each of these were runner-grafted to two normal Royal Sovereign (Indicator) plants. On 8th July the grafts were found to be successful with the exception of one on Unit 1. In the absence of any further suitable runners on the seedling-plants under test the Indicator plant in question (No. 2) was grafted again, this time on to Indicator plant No. 1. This graft also failed and a further and successful re-graft on to the same plant was made on 23rd July. Indicator plant No. 2 of Unit 1 and its runner progeny were therefore treated as an independent unit (Unit 3) and the symptoms subsequently recorded on these plants must be regarded as transmitted from the same source as in Unit 1, but at a later date and via another Indicator plant.

The constitution of the units is summarized in Table II.

TABLE II.

CONSTITUTION OF " GRAFT-UNITS ".

Unit.	Index No. of Seedling under Test.	Date of Successful Grafting.	No. of Indicator Parent Plants.	No. of Supplementary Runners.
	Cambridge Seedlings			
1	30/16/9	22nd June	1	4
2	30/17/19	24th June	2	4
3	As unit 1	27th July	1	10
	L.A. Seedling			
4	Plant 1	8th August	3	10
5	Plant 2	8th August	1	3
6	As unit 5	5th September	1	3

Instead of the usual procedure of limiting the "supplementary-runner" plants to two (on two stolons) per indicator plant, as large a number as possible were potted with the object of obtaining a supply of uniformly " Crinkle " infected Royal Sovereign plants for future experiments.

2. *Observations on Units.*

On 8th August numerous small circular chlorotic lesions (1-2 mm. diam.) were noted on the Royal Sovereign Indicators of Unit 2, scattered irregularly over the youngest leaves on the " grafted runners " and " parent-plants ". No symptoms were detectable at this time on the " supplementary runners " or throughout the other two units. In their subsequent development the symptoms were identical with those described by Ogilvie, Swarbrick and Thompson, and became so pronounced that on 28th August all the indicator plants of this unit with the majority of the supplementary runners were recorded as showing " violent crinkle ". By this time, however, the " Crinkle " symptoms were observed to be superimposed on the type of leaf curling characteristic of Yellow-edge and by early September undoubted and advanced symptoms of the latter disease, in addition to the " serious " Crinkle symptoms were recorded on all the Indicator plants and runners, although only the latter symptoms (uncomplicated by

Yellow-edge) were recorded on the plant of the seedling variety forming the source of infection. By mid-October the combined symptoms on the Royal Sovereign indicators had become so severe that certain of the runner plants resembled the so-called " cauliflower " (Plate II, Figs. 1 and 2). At this advanced stage it was just possible to detect Yellow-edge symptoms combined with those of the " serious-crinkle " on the seedling plant under test as on other non-grafted seedling plants in the collection (Plate I, Fig. 1).

Initial " Crinkle " symptoms were not recorded on the Indicator plants of Units 1 and 3 until late August. From this time steady development took place but less rapidly than on Unit 2. The " Crinkle " symptoms remained uncomplicated by those of Yellow-edge on all plants until October when, again, it became possible to detect such on the Indicator plants. It was not, however, until the early summer of 1936 that Yellow-edge could be detected on the seedling plant under test.

Observations on all units were continued until the early summer of 1936, when again both symptom types appeared, with occasional changes in the relative emphasis of each. At this time an enlargement of the spot lesions with a reddish or purplish coloration, as noted by the Long Ashton workers (4), was recorded on the older leaves of the Royal Sovereign indicators. A combined summary of the results of this and the succeeding experiment, based on individual symptom records on each plant, follows (p. 217).

V. The Long Ashton Seedling.

A. The Material.

The consignment was received from Long Ashton in mid-June and consisted of nineteen plants of a single seedling from a cross between Tardive de Leopold and Royal Sovereign, and one plant of Huxley's Giant, all in pots and said to be "Crinkle" infected.

The latter plant showed typical and advanced " Crinkle " symptoms at the time but unfortunately did not produce runners and therefore could not be used in the experiment.

The former nineteen plants were for the most part very weakly, being derived not from runners but by the splitting up of older plants. Three plants only produced runners and provided the source of " Crinkle " in the experiment. The foliage of these was of the thick and leathery type typical of *Fragaria chiloensis* (one of the parents of the cultivated varieties of Europe and North America) and at the time of arrival the present writer was unable to detect symptoms of " Crinkle " on any of them. In early July, however, Mr. Thompson visited the Station from Long Ashton and demonstrated that minute sparsely scattered chlorotic spots were to be seen when the younger leaflets of some of the plants were held against a source of light. At this time no " Crinkling " of the leaves could be detected ; by mid-October, however, spot lesions were common on all the plants, accompanied in many cases by definite " Crinkling ". At this time, also, the younger leaves of eleven plants showed the chlorotic margin, and (where "Crinkle" was not severe) the regular down-cupping of leaflets characteristic of Yellow-edge ; the symptoms of this disease, however, were not clearly defined at any time and on certain plants did not appear at all (Plate I, Figs. 2 and 3).

B. The Experiment.

1. *Lay-out.*

On 8th August three Type 1 units were set up with the runner-producing plants of the seedling variety and Royal Sovereign indicators. As it was hoped by this means to

secure a series of uniformly " Crinkle " infected Royal Sovereign plants each available runner from the seedling plants was grafted to an indicator plant, and each primary runner produced from these (beyond the grafted runners) was retained and struck into a pot.

Graft-union failed on one of the three units, the indicator of which was, therefore, set aside, and it is interesting to note that no " Crinkle " subsequently appeared on this plant. An additional unit to replace the above was set up on 5th September. Details of the constitution of these units (4-6 in the complete series) will be found in Table II.

2. *Observations on Units.*

On 5th September all the indicator plants were recorded as free from symptoms. On 16th September incipient " Crinkle " was observed on those of Units 4 and 5. By the end of October all the indicator plants, and (with one exception) the supplementary runners, of these two units were showing well-defined " Crinkle ", and at the same time definite Yellow-edge was observed on the indicators of each of the three units and the majority of their runners. It was not until June of the following year that " Crinkle " was observed on the indicators of the later-grafted Unit 6. At this time both symptom types were visible on the indicators of all units, but only the " Crinkle " type on the seedling plants under test.

VI. Summary of Results.

To facilitate the comparison of symptom-intensity from plant to plant in the above experiments a scale of five categories was adopted. Classification of a plant for "Crinkle" intensity was primarily based on the concentration of the spot-lesions on the most severely affected leaf. As the actual crinkling or distortion of the laminae is clearly the result of a retardation of leaf growth localized in the minute chlorotic areas, its intensity, therefore, depends on the concentration of the spotting, the stage of leaf development at which the spots appear, and the date of the observation. Yellow-edge plants were categorized on the aggregate degrees of chlorosis, leaf-curl and stunting of leaf petioles. The categories are summarized in Table III.

Table III.

Category.	Crinkle (C).	Yellow-edge (Y).
1	Spots widely distributed, scarce and not sufficiently concentrated to produce a noticeable Crinkle.	Faint chlorosis of leaf margins and/or slight curl. No final diagnosis possible.
2	Spots scattered over lamina, fairly numerous with slight Crinkle.	Symptoms *just* definite enough for diagnosis.
3	Spots numerous with pronounced Crinkle. A moderately severe case.	All symptoms moderately pronounced.
4	Spotting concentrated with severe Crinkle.	Symptoms severe.
5	Extreme concentration of spotting with very severe Crinkle.	Extreme severity of all symptoms. A dwarf, flat, yellow, sterile plant.

Two individual plant surveys for relative symptom intensity according to the above described system of recording were made at times when the " Crinkle " symptoms, generally, were most clearly defined (i.e. in late October, 1935, and mid-June, 1936), and the results of these are summarized in Table IV.

Table IV.

Summary of Two Surveys for Symptom Intensity on Graft Units 1-6.

Unit 1	⊗	□	1·1	2·1	3·1	4·1								
29/10/35 12/6/36	C4Y0 C2Y2	C1Y3 C4Y1	C4Y3 C4Y1	C3Y2 C5Y1	ND C5Y1	C1Y2 C4Y1								
Unit 2	⊗	□1	1·1	2·1	□2	1·1	2·1							
29/10/35 12/6/36	C4Y1 D	C4Y4 C3Y3	C1Y3 C2Y2	C3Y3 C2Y3	C5Y5 C3Y3	C5Y5 C3Y3	C5Y5 C3Y1							
Unit 3	⊗	□	1·1	1·2	1·3	1·4	2·1	2·2	3·1	3·2	4·1	5·1		
29/10/35 12/6/36	C4Y0 C2Y2	C2Y2 C2Y4	C2Y2 C1Y0	C1Y2 C1Y2	C0Y1 C3Y0	C0Y2 D	C1Y2 C2Y0	C0Y0 C2Y1	C1Y2 C2Y1	C1Y1 C2Y1	C0Y2 C1Y1	C1Y0 C1Y2		
Unit 4	⊗	□1	1·1	2·1	3·1	4·1	□2	1·1	2·1	3·1	4·1	□3	1·1	2·1
29/10/35 16/6/36	C2Y0 C2Y0	C1Y2 C2Y0	C3Y0 C2Y0	C3Y2 C2Y1	C3Y0 C3Y0	C1Y0 C3Y2	C2Y2 C2Y0	C2Y2 C3Y1	C2Y2 C3Y0	C2Y1 C3Y0	C0Y0 C3Y0	C2Y2 C2Y2	C2Y1 C3Y1	C2Y1 C3Y1
Unit 5	⊗	□1	1·1	2·1	3·1									
29/10/35 16/6/36	C2Y0 C2Y0	C1Y2 C3Y2	C2Y2 C4Y2	C3Y1 C3Y2	C2Y1 C3Y2									
Unit 6	⊗	□1	1·1	2·1	3·1									
29/10/35 16/6/36	C2Y0 C2Y0	C0Y2 C1Y0	C0Y2 C1Y1	C0Y1 C1Y2	C0Y2 C1Y1									

D = Dead. ND = Nearly Dead. C = Crinkle. Y = Yellow-edge.

In Table IV the components of each unit are set out along the line co-extensive with the unit-number, the symbols used corresponding to those of the text figure illustrating the schematic structure of type 1 units. The runner plants derived from each " parent indicator plant " follow the symbol of that plant in series. Each such runner plant is designated by a number indicating the serial number of the stolon system from which it is derived, and a second number indicating the order of the runner plant in question on that system. Thus runner 2·1 indicates the first runner plant to be produced on stolon system number 2. Under each plant symbol or number the records of relative symptom intensity for that plant on the two dates mentioned above, are set out.

The following points arise from a consideration of this table, and the summary in Table V.

(*a*) The effectiveness of Royal Sovereign as an indicator of the Yellow-edge group of symptoms is shown. Thus the seedling " Crinkle " plants in Units 4, 5 and 6 were classified as Yo in both surveys, but all of them transmitted Yellow-edge symptoms to the indicators.

(*b*) The indicator plants did not react uniformly in respect of the relative intensities of the two symptom groups, the range of variation being particularly wide in the October survey. Thus, in October symptoms on the indicators ranged from moderately severe Yellow-edge with slight " Crinkle " (C_1Y_3) to the reverse condition (C_3Y_2). This range is illustrated in Plates II, Fig. 3, and III.

(*c*) The summary in Table V shows that, at the October survey of indicator (Royal Sovereign) plants, an even balance was generally held between the intensities of " Crinkle " and Yellow-edge symptoms, but that in June of the season following infection " Crinkle " had become more intense and was dominant, while Yellow-edge was less pronounced. Unit 2 was exceptional in that both symptom groups reached maximum intensity rapidly within the season of transmission followed by a distinct amelioration of each in the following June, an even balance between both groups being maintained throughout.

(*d*) At the first survey a higher mean-maximum-intensity of both symptom groups was reached by the indicators infected from the Cambridge seedlings (Units 1-3) than on those infected from the Long Ashton seedling. This is most probably entirely due to the earlier grafting of the former. There is in fact a marked relation between the date of grafting and the maximum " Crinkle " intensity reached in October, *irrespective of the source of the " Crinkle "*. Thus, the greatest intensity is reached in Units 1 and 2 (grafted in late June), only moderate intensity by Units 3, 4 and 5 (grafted in late July and early August) and no " Crinkle " at all on the September grafted Unit 6. By June, 1936, " Crinkle " had become more uniformly severe, the highest intensity, however, being recorded on Unit 1 and the lowest still on Unit 6.

TABLE V.

SUMMARY OF SYMPTOM SURVEYS ON INDICATOR PLANTS OF UNITS 1—6.

Date of Survey.	No. of plants with relative intensities as follows :			Mean relative intensity per plant.	
	Y and C equal.	C dominates.	Y dominates.	C	Y
29/10/35	14	12	16	2	2
12/6/36	8	29	5	3	1

VII. Discussion.

By the use of certain seedling varieties as the source of disease, a group of symptoms was transmitted by runner grafting to " normal " Royal Sovereign indicator plants, fundamentally distinct in type from that transmitted to comparable plants (from the same clonal family) of this variety in the original (1932) experiment upon which the preliminary description of the Yellow-edge disease was based. These variant symptoms corresponded closely with those previously recorded as naturally occurring on Royal Sovereign plants in South-West England (4) and with the " Crinkle " virus disease in North-West America (7), thereby confirming the virus origin of the former.

The subsequent appearance, however, of Yellow-edge symptoms on the indicator plants in addition to those of the variant (" Crinkle ") types, leads to the assumption either that " Crinkle " must be added to the list of Yellow-edge symptoms, or that the plants in question were infected with two distinct diseases in association. The latter assumption, namely the distinct causal origin of the " Crinkle " type symptoms, is supported by the following considerations :

(*a*) " Crinkle " symptoms were not transmitted to the exactly comparable Yellow-edge infected Royal Sovereign plants in the 1932 experiment (2).

(*b*) Similar distinct " Crinkle " symptoms were not observed at East Malling as on Yellow-edge or " normal " Royal Sovereign plants during previous years' inspections of field plantations, and did not appear, in combination with Yellow-edge or otherwise, on the comparable Royal Sovereign plants on the Cambridge seedling trial-plot.

(*c*) Comparable " Crinkle " symptoms did not appear, either alone or in combination with induced Yellow-edge symptoms, on the Royal Sovereign indicators throughout the numerous type 2 and type 3 graft-units in the parallel series of experiments made in the same year, with English commercial varieties.

Finally it will be noted that the English variety Tardive de Leopold entered into the parentage of all the seedlings providing the source of " Crinkle " in the present experiments. Certain of the American Ettersburg Seedlings also figure prominently in the origin of the " Crinkle "-infected Cambridge seedlings ; these originated in Western North America and include varieties (such as Ettersburg 121) which are outstandingly susceptible to " Crinkle " in that country (7).

Summary.

1. Symptoms differing from those hitherto associated with the Yellow-edge disease were transmitted, together with those of Yellow-edge, by runner-grafting, from certain severely affected plants of seedling varieties (crosses between English, and English and American commercial varieties) to " normal " Royal Sovereign plants.

2. The symptoms thus transmitted corresponded closely to those previously reported by Ogilvie, Swarbrick and Thompson as occurring naturally on Royal Sovereign in South-West England, and to those of " Crinkle " in North-West America as described by Zeller and Vaughan.

3. Confirmatory evidence of the virus origin of the " Crinkle " symptoms as they occur in England was thereby obtained and the available data is considered to support the assumption that this disease is causally distinct from Yellow-edge.

Acknowledgments.

Acknowledgments are due to Messrs. Ogilvie, Swarbrick and Thompson of the Long Ashton Research Station, Bristol, for their ready assistance and co-operation both

FIG. 1.

A plant of Cambridge Seedling 30/14/32 with severe Crinkle symptoms combined with Yellow-edge. Photo. 20th October, 1935.

FIG. 2.

A plant of the Long Ashton Seedling used as the source of Crinkle in Units 5 and 6 and showing distinct Crinkle symptoms. Photo. 21st October, 1935.

FIG. 3.

A plant of the Long Ashton Seedling showing Yellow-edge symptoms. Photo. 21st October, 1935.

PLATE I.

FIG. 1.

Royal Sovereign Indicator plant No. 2 of Unit 2, with grafted and supplementary runners complete, showing combined severe attacks of Crinkle and Yellow-edge. Photo. 21st October, 1935.

FIG. 2.

Supplementary Indicator Runner with extreme symptoms. Unit 2, Indicator 2, Runner 2·1, C5V5

FIG. 3.

Leaves of Royal Sovereign Indicators selected to illustrate the range of relative variation in emphasis of each symptom-type.

Leaves 1 and 2 : Yellow-edge predominates.
3 and 4 : Equal Yellow-edge and Crinkle.
5 and 6 : Crinkle predominates.
Photo. 22nd October, 1935.

FIG. 1. Yellow-edge symptoms only. Unit 3, Runner 1·4, CoY2.

FIG. 2. Crinkle symptoms dominant. Unit 1, Runner 2·1, C3Y2.

FIG. 3. Crinkle and Yellow-edge symptoms moderately severe. Unit 2, Indicator 1, Runner 2·1, C3Y3.

FIG. 4. Crinkle symptoms only. Unit 4, Indicator 1, Runner 1·1, C3Yo.

Supplementary Royal Sovereign Indicator Runners, infected with combined Crinkle and Yellow-edge, showing the range of relative Crinkle and Yellow-edge intensities. Photos 21st October, 1925.

directly, in the provision of " Crinkle " material, and by criticism and suggestion, to Miss E. King for assistance in graft manipulation, and plant recording, to Mr. Arthur Tidy for his skilful care of the plant material throughout, and to Miss K. E. Cornford for taking the photographs.

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ENTOMOLOGY

NOTES ON SOME INTERESTING MITES AND INSECTS OBSERVED ON FRUIT TREES IN 1936

By A. M. MASSEE

1. *Eriophyes piri* var. *arianus* (Can.) Nal.

A number of leaves from a White Beam tree growing in a garden in North Somerset were sent to East Malling in June, 1936. The injury to the foliage appeared to be typical of that caused by a species of Gall Mite. A detailed examination confirmed this view, and the species proved to be *E. piri* var. *arianus* (Can.) Nal., a species very closely allied to the more familiar Pear Leaf Blister Mite.

This appears to be the first record of this acarus in Britain. The mite causes little leaf galls or " pocket galls " on the upper surface. They occur in little groups and their entrance is on the under surface. When mature they are yellowish-green to reddish-brown. A systematic description of the mite by Nalepa appears in *Marcellia*, 1925, Vol. V, pp. 65-6.

It seems most unlikely that the mite will ever prove to be of economic importance, but since it is the first record of its appearance in this country it seems worth while mentioning it here.

2. The Fruit Tree Red Spider (*Oligonychus ulmi* C. L. Koch).

It is evident that a good deal more knowledge is required regarding the life-cycle and habits of this important pest. It is generally considered to be more abundant in fruit plantations in seasons when there happens to be a prolonged dry summer. This season, however, proves to be an exception. It was naturally thought that the prolonged wet and sunless periods would check the breeding activities of the Fruit Tree Red Spider. On the contrary, however, it was abnormally abundant from the latter part of July onwards, and in some localities it was prevalent throughout the season.

This pest has been particularly common in the Maidstone district, Marden and East Malling. In one orchard at East Malling it has persisted in spite of the application of three post-blossom lime-sulphur sprays.

It is curious also that derelict orchards which have never been sprayed with a tar-distillate winter wash are still free of this pest, and it suggests that some predaceous insect (as yet not known) may be responsible.

3. The Apple Fruit Rhynchites (*Rhynchites aequatus* L.).

The Apple Fruit Rhynchites or Apple Fruit Weevil will soon be regarded as a primary pest if it continues to spread at its present rate.

Very severe outbreaks have been noted in the Southfleet area, and it has been more common than usual in the Maidstone district. For many years it has been well known

to attack apple fruitlets, but this season appears to be the first in which it has become economically important on plum and damson.

The infestation at Southfleet was so bad that one or more of these little red weevils, with a long snout, could be found damaging most of the fruitlets over an area of ten acres.

In the same district an orchard of Newton Wonder apples was also infested and a large proportion of the fruitlets were rendered useless.

The migration to apple seems to begin during the flowering season and the fruitlets are punctured as soon as they commence to grow, most of the damage being done from petal-fall until the third week of June. They attack plums a little sooner than apples, but since they remain on the trees until the third week of June the damage is often more severe.

As mentioned in earlier reports the damage is caused by the weevils boring into the flesh of the fruits with their snouts, with the object of depositing an egg in the hole subsequently. In practice, however, very few eggs have been found in the punctured fruitlets.

The application of a derris dust seems to be a fool-proof remedy against this insect, but it must be applied soon after petal-fall, or much of the damage will have been done. Should the infestation be very severe more than one application may prove necessary.

More details concerning this insect, together with an illustration of the damage caused by it, appeared in the East Malling Research Station Annual Report for 1931 (A15), p. 53.

4. Flower Beetles.

A large number of some of the smaller British beetles are attracted to the blossoms of apple, pear, plum, cherry, etc., every year. Some twenty species are regular visitors during the blossom period in the East Malling district.

These beetles most of which do not possess popular names are considered to be beneficial. The scientific names of some of the more common species are given as a matter of interest. *Meligethes aeneus* F.; *Atomaria linearis* S.; *Micrame vini* Pz.; *Corticaria elongata* Gy.; *Anaspis humeralis* F.; *Corticarina gibbosa* Hb.; *Enicmus transversus* Ol. and *Byturus tomentosus* Fab.

These small beetles differ in their habits from hive and wild bees and many of the two-winged flies because they remain in the blossoms irrespective of the weather conditions prevailing at the time. It is considered that in their travels from blossom to blossom they must assist to some extent in pollinating the flowers. It is common to find them covered with pollen, and the fact that they fly readily, suggests that they travel some distance in the orchard.

The hive bees and other winged insects, on the other hand, are more plentiful in the orchard on warm, sunny days, and they are almost entirely absent if the weather is cold and unsettled.

Many fruit growers have made enquiries about these small beetles, but it is clear from the above remarks that they are not harmful, at least to blossoms of fruit trees.

In the list given above it will be noted that two species, namely *B. tomentosus* Fab. (The Raspberry Beetle) and *A. linearis* S. (The Pigmy Mangold Beetle) are very familiar pests on the raspberry and mangold crops respectively, yet on apple and other fruit trees they must be regarded as beneficial insects.

5. Wood Boring Beetle in Apple Fruitlet.

An apple fruitlet sent to the Research Station in June, from a neighbouring farm, was found to contain a female specimen of a wood boring beetle closely allied to the Stag Beetle. The beetle proved to be *Dorcus parallelopipedus* L., and on its arrival it was still engaged in removing small pieces of the flesh of the apple, the centre of which was completely hollowed out. When given another fruit it started to repeat the process, but died a few days later without completing its work. It is curious that an insect of this nature should destroy an apple in this manner, but it is very unlikely that a similar incidence will be noted for many years to come.

6. Wasp Beetle (*Clytus arietis* L.).

The Wasp Beetle, so-called because of its close resemblance to a wasp, proved to be unusually common in an apple orchard at Wisboro Green, West Sussex.

It is one of the true wood boring beetles which are generally associated with dead or dying trees. Its abundance in the orchard in West Sussex can be accounted for by the fact that stacks of wood of dead apple trees were lying on the headlands of the orchard, and the beetles were breeding in trunks of the decaying trees.

This beetle has been noted also in the stems of plum trees. It is unlikely, however, that it will attack trees which are in a healthy growing condition.

7. The Blister Beetle (*Lytta vesicatoria* L.).

Although the very beautiful, brilliant, metallic green Blister Beetle is not associated with fruit, it is of interest to record this rare beetle from Stourmouth in Kent.

Some hundreds of this beetle were found feeding on a privet hedge, which surrounded a tennis court, in a garden of a farm house.

The beetle emits a very pungent smell, which is particularly noticeable when it takes to the wing on sunny days. It was the very unpleasant smell which attracted the farmer's notice to the insect. At first it was thought that a sheep or some other animal must have died near the farmhouse.

The beetles were first noticed about the middle of July, and they remained feeding voraciously on the privet leaves until August. The beetle lays yellow, cylindrical eggs in a mass in the hard, bare ground, and the grubs on hatching are predaceous, feeding upon certain species of wild bees.

8. A Long-horned Beetle attacking Cherry.

Several grubs of one of the largest British Long-horned beetles were found feeding within the main roots of some old cherry trees growing in an orchard in the Tenterden district. Their tunnelling and feeding caused many of the roots to die, and apparently for this reason many trees had to be removed.

The insect responsible proves to be *Prionus coriarius* L. which is somewhat local, but has a widespread distribution. Its normal host plants are Oak, Beech, Horse Chestnut and Ash according to Fowler. It is curious, therefore, that it should be found on cherry.

9. Lappet Moth (*Gastropacha quercifolia* L.).

The caterpillar of this very handsome brown moth is occasionally noted hibernating on apple trees during the winter months, but as a general rule only single specimens are

found. It is of interest, therefore, to record that a large number of these caterpillars were found in a young apple orchard at Ditton in the spring. The caterpillar, which is flat and brown, stretches itself out, closely and tightly gripped to a shoot or spur, and in this position it is very difficult to detect. When fully fed it makes a large silken cocoon, attached to a number of leaves. The moth emerges in June and July.

10. Lobster Moth (*Stauropus fagi* L.).

The caterpillar of the Lobster Moth, so-called because of its resemblance to the crustacean, normally feeds upon the foliage of beech and oak, and occasionally upon other trees.

Several specimens of the caterpillar were noted on apple in the East Malling district and because of its peculiar structure fruit growers are naturally curious to find out more about it. In addition to apple, it has also been found feeding upon the wild crab apple.

The caterpillar, which is never likely to become a pest, feeds on the leaves during the summer months. The cocoon is spun up in the leaves in autumn, and it remains in the chrysalis stage until the following June. The moth emerges in June and July.

11. The Currant Clearwing (*Conopia tipuliformis* L.).

The Currant Clearwing is usually present in small numbers in most established currant plantations in the south-east of England, but during the past two years reports indicate that this pest has been abnormally common.

One Kentish grower found this insect so plentiful on some black currants in the nursery bed that it was considered to be unwise to transport them without cutting back the new growths to ground level.

The caterpillar is a stem borer which tunnels in the pith of the shoots in an upward direction. If the bushes are young and it is proposed to cut them back before transplanting them, the pest matters but little. It is on established bushes that the problem of control becomes difficult. All that can be done is to examine the shoots carefully when pruning and regulating operations are in progress in the winter months, and those which have been tunnelled by the caterpillar should be cut back until sound wood is reached. The infested shoots are usually quite brittle, and snap readily when bent over.

12. Wood-Boring Caterpillars infesting Young Apples.

The wood-boring caterpillars of the Goat Moth and the Leopard Moth have been unusually common of late years. Goat Moth infestations have been reported from many parts of Kent and also by gardeners in the London district. Enquiries regarding the Leopard caterpillar have been general, most enquiries concerning young apple plantations in Kent, Sussex and Essex.

Both these insects have been known to infest fruit trees for many years, and it is possible that the greater care given to young trees now than formerly accounts for " workings " made by these insects being noticed more frequently.

If a branch is found to be tunnelled by one of these insects it is advisable to remove the whole branch. If this is not desirable because it unbalances the shape of the tree, the caterpillar may frequently be removed by means of a piece of flexible wire. Where this is not possible a small piece of cyanide should be pushed into the gallery and the entrance plugged up by means of clay or stiff soil.

13. Apple Tortrix Moth (*Cacoecia podana* Scop.).

The fruit surface eating caterpillar of the Tortrix Moth caused considerable damage to apples in the later part of July, August and September. It proved to be very common in the Maidstone district, and the damage caused by it was particularly noticeable at the local Kent fruit shows in the autumn.

In addition to apple, this caterpillar also feeds upon blackberry, cherry, damson, hawthorn, pear, quince, raspberry and walnut. This year it has been recorded on three more host plants, namely, red and black currant and poplar. It seems to be very partial to the poplar, and a large number were bred from the poplar windbreak adjoining an apple plantation at East Malling.

14. Currant Shoot Moth (*Lampronia capitella* Cl.).

The Currant Shoot Moth is considered to be a somewhat local insect in Kent, but in some seasons serious outbreaks occur, usually in the Canterbury district. A very bad outbreak was reported from Stone Street, near Sevenoaks. In this instance the infestation was so bad that several acres of September Black were destroyed and had to be grubbed. The caterpillar stage of this moth is responsible for the damage. After hibernating as a caterpillar, in a silken case, attached to a bud, it commences to feed again in the spring. It tunnels into the buds and shoots, causing them to flag, and eventually dry out. It is very partial to the fruiting buds, which often results in severe loss of crop.

A closely allied species occurs on raspberry, but fortunately it is not common in the commercial plantation. An outbreak was noted, however, at Kingsdown, near Wrotham, Kent.

15. Codling Moth (*Cydia pomonella* L.).

It will be remembered that the Codling Moth was unusually common in Kent and elsewhere in 1936, and many fruitgrowers were wondering whether it was going to be a serious pest for several seasons, or whether its abnormal abundance was due to the exceptional seasonal conditions prevailing that year.

Fortunately, the Codling Moth has not been common, and, indeed, many growers have not been troubled by this pest at all. It should be made quite clear, however, that the Codling Moth is still about in the fruit plantations in small numbers, and when seasonal or other conditions are suitable it will become troublesome again.

When the infestation is slight, the maggoty apples usually fall off the tree, and thus they are often unnoticed by the grower.

Several outbreaks were noted in North Kent, and a severe infestation was reported from Southfleet. Five per cent. of the total apple crop was found to be infested with Codling maggots in a five acre apple orchard at East Malling.

As is usually the case the amount of infestation in the private gardens seems to be greater than that in the commercial orchard.

The Codling Moth maggot hibernates under loose bark, etc., on the trunk of the tree, and it turns into the chrysalis stage in the spring. Very few maggots were noted after May 27th; by that date the majority were in the chrysalis state. One adult moth was noticed flying in an apple orchard on the same date.

16. Apple and Plum Sawflies.

Some interesting observations have been made upon the Apple Sawfly and Plum Sawfly in the East Malling district during the spring months.

Several orchards which bore no crop in 1935 were visited regularly during the blossom period and both the Apple and Plum Sawfly were plentiful and were actually observed depositing their eggs in the flower trusses. The fact that these two insects were abundant in orchards which bore no crop last season, needs some explanation. Two possibiilities seem likely : (1) that some of the caterpillars, which are known to fall to the ground and enter the soil for wintering purposes, remained there for two seasons before maturing ; (2) that the adult Sawflies, both species of which can fly readily, migrated from some other infested orchard in the district and started a new infestation elsewhere. Of these two possible explanations the first appears to be the more likely one.

Such interesting points as these tend to show that very little is known about some of our most important insect pests, and suggest that a more detailed study of their habits should be made in future investigations.

17. Dock Sawfly (*Ametastegia glabrata* Fall.).

The green caterpillar of the Dock Sawfly is an insect with very curious habits. Normally it feeds upon the dock which frequently abounds in orchards and more particularly on the headlands. When the caterpillars are fully fed in the autumn they seek hibernation in cracks in posts of fences, in dead grass stems, etc. Another favourite wintering quarter is in the pithy portion of the "snag" remaining when the fruiting canes of raspberry have been cut out. In addition to such situations, however, the caterpillars will in some seasons cause considerable damage by boring into mature fruits while they are still on the tree, or more frequently when picked and left in the orchard in boxes. The caterpillar bores a straight, cylindrical hole into the fruit, varying in length from a quarter of an inch to one inch. For some reason, they rarely remain in one bore for any length of time, but they prefer to wriggle their way out, and commence to bore again elsewhere. These insects frequently cause considerable damage, and in one instance a large number of fruits were ruined.

Many enquiries have been received concerning this insect, mainly from the counties of Kent, Sussex and Essex. One enquiry from Chelmsford, Essex, proved to be of particular interest. The caterpillar was found boring into the apples in the usual manner, but, in addition, numbers were found hibernating in the dead portion of the spur growths which had been cut back the previous season. Many of the tips had died back an inch of so from the cut, these portions had shrivelled and split open allowing sufficient room for the caterpillars to creep into for hibernating purposes.

18. Apple Capsid Bug (*Plesiocoris rugicollis* Fall.).

The Apple Capsid Bug is still very troublesome in many parts of Kent, and it is still rightly regarded as being one of the most important apple pests.

Fortunately, many fruitgrowers are able to check it sufficiently by means of a petroleum oil spray to render it commercially unimportant. The secret of success in this respect seems to depend upon two factors: (1) the date of application of spray, and (2) the thoroughness with which the spray is applied. Many growers purposely delay their capsid wash until the latter part of March. This late application is fully justified by the results obtained.

Thus, while the Apple Capsid Bug is being mastered by many growers—usually those with up-to-date spraying tackle—it is still very troublesome over a wide area of Kent. In many parts of Kent it was not so abundant as usual, but, on the other hand, small outbreaks have occurred in most orchards, and this presents a distinct difficulty.

The grower has to decide whether it will be necessary to spray the entire orchard or whether it will be sufficient just to apply petroleum to the bad patch. The grower must use his own discretion on this matter. It is always advisable to mark bad patches in any particular orchard before the fruit has been gathered, for then the grower is able to examine the " bad patch " in detail the following spring.

The Marden district has not been affected by this insect to any extent until the last two seasons. Now, unfortunately, it appears to be establishing itself in several widely separated orchards in the neighbourhood. Growers are advised to keep a strict look-out for this insect, and when an outbreak is discovered, the latest control measures available should be followed to ensure its destruction before it becomes firmly established in the district.

19. A Plant Bug on Plum.

A number of Pentatomid or Shield Bugs, of the species *Sehirus bicolor* L., were found feeding on plum foliage in an orchard at Brenchley, Kent.

One of the bugs deposited a batch of twenty-eight eggs on the under surface of a plum leaf. All the eggs hatched on the same day, namely, 1st August, 1936. A description of the egg is appended as a matter of scientific interest since it is not described in E. A. Butler's Book on British Hemiptera-Heteroptera, published in 1923.

The egg is yellow, and barrel-shaped with a rounded base. There is a black-edged triangular process attached to the side of the shell near the lid. The empty egg case is of a dirty, pearl-white colour. The bug escapes from the egg by way of the hinged lid at the cap of the egg.

Length of egg 1·4 mm., diameter 0·8 mm.

Summary.

Brief notes are given of mites and insects which were found associated with fruit trees and bushes in 1936, special attention being paid to those of economic importance. Some insects not usually associated with fruit trees are also noted in brief.

STUDIES ON THE TRANSMISSION OF THE STRAWBERRY VIRUS "YELLOW-EDGE" DISEASE BY INSECTS

III. APHID TRANSMISSION EXPERIMENTS AND PERIOD OF INFECTIBILITY

By A. M. MASSEE

The experiments carried out in 1934 clearly demonstrated that the Strawberry Aphid (*Capitophorus fragaefolii* Ckll.) is a vector of the strawberry virus disease "Yellow-edge", and in the following year further investigations proved that the same aphid is able to transmit the virus from infected plants to "Yellow-edge" free ones during the months of May, June and July respectively.

The experiment described below was designed to ascertain whether the same species of aphid can transmit the virus at other periods of the year, namely, in March, April and in August.

Experimental Material.

The investigations of 1936 have been carried out on lines exactly similar to those of the previous two seasons. The plants were raised from the same clonal material, and were plunged in pots on the same site as before.

Treatment of Plants.

Since the treatment of the plants was precisely the same as in former experiments details need not be repeated here. Full particulars appear in the East Malling Research Station Annual Report for 1935.

Source of Aphides.

The colony of aphides bred in 1935 survived the winter of 1935-6 and a strong colony was available for the March inoculations. The aphides were bred again on the same "Yellow-edge" plant which had been used for this purpose since the initial experiment.

Direct Inoculations.

The March inoculations were made on the second and seventh days of the month, a total of five aphides being placed on the under surface of the young leaves of each of thirty plants. The April inoculations were made on the 3rd and 8th of the month,

the aphides being obtained from the same source as the March ones, and a similar number were transferred to each plant. The August inoculations were made on the 4th and 10th and were similar to those made earlier in the year.

Examination of Plants.

The plants were examined periodically during the growing season, and more detailed surveys of the plots were made in April, June, July and October when height and spread records of each of the plants were also obtained.

The initial survey made during the latter part of April proved to be of interest. The majority of the plants on the plot which had been inoculated with aphides from the virus plant in early March showed distinct signs of flattening but the typical " Yellow-edge " symptoms were not apparent. It was evident, however, that these plants were behaving very differently from the rest.

By the second week of June the plants inoculated in March were just beginning to show distinct " Yellow-edge " symptoms, which, however, were much more pronounced by the first week of July.

Of the plants inoculated in April the characteristic aphid leaf-curl symptoms were conspicuous by the end of that month, and all of them were exhibiting the " flattened " appearance by the end of the month. By the end of June the characteristic " Yellow-edge " symptoms were conspicuous on twenty-four of the thirty plants.

At the time of the third survey made at the end of July, twenty-eight of the plants inoculated in March were now showing distinct virus symptoms, while twenty-four of those inoculated in April were similarly affected.

By the first week of September the plants inoculated in March were much less vigorous than the control series, but it is of interest to note that two plants were still growing vigorously and stood out from the rest in the series by their upright habit, and the fresh green appearance of the foliage.

Twenty-five of the plants inoculated in April were obviously infected by September while the five remaining were considered to be distinctly doubtful cases.

A further examination at the end of December showed that of the plants inoculated in March, two were still apparently quite healthy. Of the April series twenty-five exhibited distinct " Yellow-edge " symptoms, while five showed mild symptoms of the disease.

The series of thirty plants inoculated in August developed typical aphid leaf-curl symptoms by the end of that month, and they were beginning to flatten by the second week of October. The " Yellow-edge " symptoms were distinct on all plants by the first week of November. It must be emphasized, however, that none of the plants inoculated in August flattened to the same extent as those inoculated in the spring months, nor were they exhibiting the advanced symptoms of the disease.

The sixty control plants need be referred to only in brief. These plants, in common with the whole clone used in the experiment, were not so robust as those used the previous year. The majority, however, remained free from " Yellow-edge " throughout the year. At one period in July the plants turned a sickly yellowish-green colour, and were considered suspicious cases of virus. By August, however, they recovered their natural colour and could be regarded as normal plants, except six which developed definite " Yellow-edge " symptoms and were removed. The first case was noticed in July, three in August and two in September.

A clearer conception of the behaviour of the plants on the various plots can be obtained by reference to the table showing the height and spread records given below.

TABLE SHOWING AVERAGE HEIGHT AND SPREAD IN INCHES OF ROYAL SOVEREIGN STRAWBERRY PLANTS.

Date of Record.	Height and Spread Records.	Plot 1. Aphides from virus plant. (March.)	Plot 2. Aphides from virus plant. (April.)	Plot 3. Control (Series 1).	Plot 4. Control (Series 2).	Plot 5. Aphides from virus plant. (August.)
26.4.36.	Height.	2·8	2·6	2·3	2·6	2·4
	Spread.	7·1	6·8	6·4	6·6	6·2
9.6.36.	Height.	4·4	4·2	5·4	5·3	5·1
	Spread.	13·3	13·0	13·2	13·7	13·1
30.7.36.	Height.	4·2	4·0	6·7	6·6	6·3
	Spread.	14·0	13·9	16·6	16·6	16·0
6.10.36.	Height.	4·2	4·4	7·1	6·8	5·9
	Spread.	12·4	12·5	16·7	17·0	17·1

It will be seen in the Table that the height and spread records of the two control plots are very similar, which indicates how very evenly the two series of plants were growing throughout the season.

The height records also demonstrate very clearly the difference of the height of the plants on plots one and two as compared with the control series. The difference in height as shown by the first two records is not well defined, but the last two records show that the plants inoculated in March and April are much more flattened than the controls.

The figures for the plants inoculated in August (Plot 5) are also of interest. The first three records show very little difference between the inoculated ones and the controls, but the difference in the height of the inoculated plants begins to stand out in the final record when it will be noted that the average height is one inch less than that of the controls.

The writer is greatly indebted to Mr. G. H. L. Dicker, B.Sc., for valued assistance in the 1936 investigations.

SUMMARY.

The results of the experiments carried out in 1935 and 1936 show that the Strawberry Aphid (*Capitophorus fragaefolii* Ckll.) is able to transmit the virus " Yellow-edge " disease from diseased to healthy Royal Sovereign strawberry plants during the months of March, April, May, June, July and August respectively.

These investigations also show that after inoculation, the typical aphid leaf-curl symptoms are first noticeable; these are followed by the " flattening " effect, and finally the characteristic " Yellow-edge " symptoms appear.

STUDIES OF IMPREGNATION OF TREE BANDING MATERIALS

III. APPLE BLOSSOM WEEVIL AND CODLING MOTH EXPERIMENTS IN 1936

A PROGRESS REPORT

By A. M. MASSEE, R. M. GREENSLADE and J. H. BRAIR

Origin of Work with Trap Bands at East Malling.

Work on the control of Apple Blossom Weevil (*Anthonomus pomorum* L.) by trap bands was started at East Malling in 1920. (Hatton 1921, Worsley 1922, Massee 1925.) It was found that weevils sheltered under the strips of sacking used to protect the bark of young trees where they were tied to stakes. This suggested that similar strips of sacking could be tied round all trees to trap the weevils, and an experiment was carried out comparing this method with the methods recommended at that time for the control of Apple Blossom Weevil. These were the use of poultry under the trees, shaking the trees and collecting the fallen weevils, lime washing, and lead arsenate spraying (Massee 1925, 1927). Hens were found to dislike Apple Blossom Weevils, although useful against the Brown Leaf Weevil (*Nemoicus oblongus*). Shaking the trees was also ineffective and it may be noted here that experiments with grease bands showed that Apple Blossom Weevils fly readily and are not incapable of using their wings as had been supposed. By lime washing at the end of March it was possible to hit more than 60 per cent. of the weevils but in spite of being caked up with lime they continued to be active and to breed normally. Lead arsenate applied just before the flowers open was equally useless. Sacking bands were found to give the best control and the method of using them was worked out.

Materials used for Banding.

As this method of trapping proved successful other materials were used in comparison with sacking. Paper was not attractive to the weevils, but in 1929 sacking was found to be less attractive than carpet felt or corrugated cardboard. The average number of weevils per band was 390 in the corrugated cardboard, against 206 in the felt and 40 in the sacking. The cost of using corrugated cardboard, including labour, was equal to using old sacking and only half the cost of new sacking. (Massee 1930.)

Use of Impregnated Bands.

These corrugated cardboard bands became a commercial practice for trapping Apple Blossom Weevil, but in some districts they were so damaged by birds in search

of the contained insects that they became useless. It was thought, therefore, that the bands might be impregnated with some substance which would repel birds but not insects, or which might even repel birds but attract insects. In 1934 an experiment was carried out in collaboration with Imperial Chemical Industries Ltd., using corrugated cardboard bands impregnated with a series of chlorinated naphthalenes known as "Seekay" waxes. (Greenslade, Massee and Thomas 1935.) The materials used were :

Seekay wax AX.111 in trichlorethylene.
,, A.68 ,,
,, A.93 ,,
,, A.123 ,,
,, A.68 in orthodichlorobenzene.
,, A.68 + 30% paradichlorobenzene in trichlorethylene.
A Seekay wax in creosote oil.
Tetrachlorbenzene in trichlorethylene.
Control bands (untreated).

Some of these treatments were promising, so the whole series were tried again on 500 twenty-year-old trees in 1935. (Greenslade and Massee 1936.) About this time the Codling Moth was becoming more common in Kent and larvae were found hibernating in the bands, so the records were extended to include this pest, and a band treated with β-naphthol, as used in the United States, was included. The results obtained in 1935 were similar to those of 1934 and are summarized in Table II.

Experiments in 1936.

During 1934 and 1935 the material A.68 was the most attractive to Codling Moth Larvae and AX.111 to weevils. These were used in 1936 in comparison with β-naphthol and untreated bands. In the 1935 experiments β-naphthol seemed to repel weevils, whereas in another locality a commercial two-inch band treated with β-naphthol in lubricating oil was found to catch weevils. In order to throw some light on this the 1936 experiment included five varieties of the β-naphthol treatment. These were the commercial two-inch bands and four-inch bands treated with β-naphthol in trichlorethylene (which evaporates completely), lubricating oil and cotton seed oil respectively to test the effect of the solvents, and the β-naphthol in lubricating oil was used at two concentrations (25 per cent. and 80 per cent. of the weight of the dry band). The "Seekay" Wax AX.111 was also used at two concentrations. These materials are shown in Table I.

The bands were put on the trees on 19th May, 1936 and those containing 80 per cent. β-naphthol and the commercial band were very unpleasant to handle, the others being less unpleasant. The trees were not so rough as last year as they had been scraped on 6th January and treated up to the fork with hot grease banding material as a protection against rabbits. The surface of this was dry enough to offer no obstruction to weevils or codling larvae by the time they were seeking shelter for hibernation.

Bird Damage.

Weekly records were taken of damage by birds to the bands. The Seekay Wax treatments and the controls were damaged to some extent but the β-naphthol treatments were not. The damage was considerably less than last year.

Treatment.	No. of bands.	Damaged bands.	Per cent. damaged.
Control (untreated)	102	37	37
AX.111 15% in trichlorethylene ..	44	11	25
A.68 ,, ..	43	8	19
AX.111 50% ,, ..	44	4	9
Other treatments (β-naphthol) ..	263	0	0

Time of Hibernation.

From 16th September to the middle of October ten untreated bands were changed every week to find the latest date at which codling larvae were going into hibernation.

Date.	Larvae. (Total for 10 trees.)
16.9.36	276
23.9.36	34
30.9.36	26
7.10.36	3
12.10.36	6

This showed that the bands should certainly not be removed from the trees before the middle of October as there are still a few larvae seeking shelter then. There had been no cold spell of weather before the last bands were removed.

Examination of the Bands, 1936.

Between 12th and 16th October the bands were removed and all Codling larvae and Apple Blossom Weevils counted. All other insects and other animals in the bands were recorded. It is interesting to note that 250 species have been found in the course of these experiments. (Massee 1930, 1935.) The average number of Codling larvae and Apple Blossom Weevils caught by each treatment is shown in Table I.

Table I.

Treatment.	No. of bands.	Average per tree.			
		Weevils		Codling Larvae	
		in band.	on bark.	in band.	on bark.
Control (untreated)	102	132·1	14·3	14·6	6·2
Seekay Wax A.68 in trichlorethylene	43	17·9	25·3	10·4	6·1
Seekay Wax AX.111 in trichlorethylene 50% ..	44	101·3	16·3	13·7	4·2
Seekay Wax AX.111 in trichlorethylene 15% ..	44	91·3	20·4	15·6	4·2
β-naphthol in trichlorethylene	44	2·5	20·3	7·4	3·4
β-naphthol in lubricating oil 80%	43	4·4	7·7	8·2	2·2
β-naphthol in lubricating oil 25%	44	13·2	12·2	6·8	2·4
β-naphthol in cotton seed oil	44	1·5	10·7	4·0	3·6
β-naphthol (commercial 2 in. band)	88	5·2	14·8	10·1	3·1

In all, 31,714 weevils were counted, about three-quarters being in the band and one-quarter on the tree, and 7,236 Codling larvae of which four-fifths were in the band. These results are compared with previous years' results in Table II.

TABLE II.

Treatment.	Average No. Weevils per band.			Average No. Codling Larvae per band.		
	1934.	1935.	1936.	1934.	1935.	1936.
Control (untreated)	9·6	23·9	132·1	0·2	32·2	20·8
A.68 in trichlorethylene	1·0	12·4	17·9	1·5	99·9	16·5
AX.111 in trichlorethylene 50%	18·2	91·1	101·3	0·9	64·2	17·8
AX.111 in trichlorethylene 15%	—	—	91·3	—	—	20·0
β-naphthol in trichlorethylene	—	—	2·5	—	—	10·9
β-naphthol in lubricating oil 80% ..	—	0·1	4·4	—	75·0	10·4
β-naphthol in lubricating oil 25% ..	—	—	13·0	—	—	9·2
β-naphthol in cotton seed oil ..	—	—	1·5	—	—	7·6
β-naphthol (commercial 2 in. band) ..	—	—	5·2	—	—	13·2
A.93 58% in trichlorethylene	3·1	23·1	—	1·5	92·8	—
A.123 45% in trichlorethylene	6·9	62·4	—	0·8	70·6	—
A.68 80% in orthodichlorobenzene ..	2·1	26·9	—	0·8	97·9	—
A.68 +30% paradichlorobenzene in trichlorethylene	3·0	30·2	—	0·5	86·8	—
A Seekay Wax 81% in creosote oil ..	0·0	1·8	—	0·3	74·6	—
Tetrachlorbenzene. 6% in trichlorethylene	10·2	52·3	—	0·2	77·5	—

In Table II the figures for Codling larvae represent the number in the band and on the bark under the band since all are usually destroyed in commercial practice. In the case of weevils only those in the bands are included, as most of the weevils on the trunk fall when the bands are removed and they are not killed.

The results this year were somewhat surprising. The untreated control bands were more attractive to weevils and Codling larvae than any of the treated bands, whereas last year all treated bands were more attractive to Codling larvae and some were more attractive to weevils. The reason for this change is not clear but there is one possible explanation. This year there was comparatively little bird damage. Although 37 per cent. of the untreated bands were damaged, it was all slight damage. During 1934 and 1935 hardly any control bands were undamaged and most were badly torn. It is possible, therefore, that the number of weevils and larvae recorded then was an even less accurate measure of the number trapped than was supposed. On the other hand, in America the commercial β-naphthol bands have been shown to be more attractive than untreated bands. The Seekay wax treatments selected on the results of the year's work in 1935 were again in 1936 better than the β-naphthol treatments, though not so good as the controls. Among the β-naphthol bands those containing 25 per cent. of their weight of β-naphthol in lubricating oil were the most attractive to Apple Blossom Weevil (Tables I and II). This suggests that it is a high concentration of β-naphthol which repels the weevils and not the solvent. The commercial band is not protected by grease-proof paper so that the corrugations are open at the top and it is possible that rain running through the bands removed some β-naphthol in spite of the oil and so made them slightly more attractive to weevils last year.

In view of the very encouraging results obtained in 1935 it is proposed to continue the trial again in 1937, because the abnormal weather conditions prevailing in 1936 may have in some measure accounted for poor results recorded in that year.

Codling Population in the Orchard.

From 6th June to 2nd October all dropped fruits were picked up every week from thirty selected trees of three varieties distributed about the plot. They were examined for Codling damage and the picked crop from these trees was also examined making a total of 79,930 fruits. Of these, 52,643 fell before Codling attack began and of the remaining 27,287, 5·1 per cent. was infested (Lane's Prince Albert 6·6 per cent., Bramley's Seedling 3·6 per cent., Newton Wonder 7·0 per cent.) and of the picked crop 1·0 per cent. was infested (Lane's 1·7 per cent., Bramley's 0·2 per cent., Newton 1·8 per cent.). These figures suggest that Bramley's Seedling is less attractive to the moths than the other varieties, but this is due to the greater number of fruits per tree on this variety. The study of the number of damaged fruits on each of the thirty test trees shows that the average population per tree is actually greater on Bramley's than on Newton Wonder or Lane's Prince Albert. The number of larvae per tree is not apparently affected by the position in the orchard.

The total population in the orchard was roughly estimated as shown in Table III.

Table III.

Variety.	No. apples examined from beginning of Codling damage to end of picking.	No. damaged by Codling.	Average population per tree.	No. trees.	Estimated population.
Lane's Prince Albert, 11 trees	4,019	264	24	245	5,880
Bramley's Seedling, 8 trees ..	14,338	520	65	127	8,255
Newton Wonder, 11 trees ..	8,930	605	55	124	6,820
Total 30 trees ..	27,287	1,389	46·3	496	20,955

The proportion of this estimated total caught by each treatment in 1936 is shown in Table IV.

Table IV.

Treatment.	Average Codling Larvae per band.	Total catch if the whole plot were treated alike.	Percentage of total estimated population.
Control (untreated)	20·8	10,316·8	49·2
Seekay Wax A.68 in trichlorethylene ..	16·5	8,184·0	39·0
Seekay Wax AX.111 in trichlorethylene 50%	17·8	8,828·8	39·5
Seekay Wax AX.111 in trichlorethylene 15%	20·0	9,920·0	47·3
β-naphthol in trichlorethylene	10·9	5,406·4	25·8
β-naphthol in lubricating oil 80%	10·4	5,158·4	24·6
β-naphthol in lubricating oil 25% ..	9·2	4,563·2	21·8
β-naphthol in cotton seed oil	7·6	3,769·6	18·0
β-naphthol commercial band	13·2	6,547·2	31·2

From these figures it seems that approximately half the total Codling population of the orchard would have been trapped if all trees had been banded with untreated material. This alone would be worth doing and as a supplementary measure to spraying

would be even more valuable. (During this experiment no spring or summer spraying against Codling was carried out.) The β-naphthol-treated bands were very much less attractive this year than untreated bands. The Seekay waxes A.68 and AX.III were more attractive than β-naphthol both to weevils and Codling larvae and almost as attractive as untreated bands but less susceptible to bird damage. These results cannot be discussed very fully until further work provides the explanation of difference between this year's findings and those of previous years.

All damaged apples were cut open and examined for the point of entry of Codling larvae and it was found that approximately two-thirds entered by the eye.

Variety.	Eye Entry.	Side Entry.
	%	%
Lane's Prince Albert	59·2	40·8
Bramley's Seedling	65·1	34·9
Newton Wonder	66·6	33·3

Apple Blossom Weevil.

Eggs were first noted in buds on 6th April but weevils were still laying on 30th April. Pupae were found on 19th May and adult weevils began emerging on 4th June. Table I shows that only one treatment, Seekay wax AX.III, caught many weevils and even this was not so good as the untreated bands. This treatment was very much better than the controls last year, though the relation between AX.III and A.68 was then much the same as this year. The figures for the number of fruits examined from the thirty trial trees are interesting at this point. The crop picked from these thirty trees amounted to 20,395 fruits. The "drop" from the beginning of Codling infestation to picking time was 6,892, but the natural "drop" before then, including the so-called "June drop", was 52,643 fruits. Now if 59,535 fruits dropped, more than twice the picked crop, and still left a crop which was considered good, it follows that the blossoms killed by weevils did not matter and in this particular case the weevil is not a pest of economic importance. It was noted, however, that weevil larvae were very seldom found in the king bud, so that if this is at all general it means that the king apple is left at the expense of better fruit. Before the weevil can be classed as harmless it would be necessary to find out what proportion of the buds it normally attacks and whether it chooses buds whose fruit would otherwise have fallen from physiological reasons or those which would have developed into mature fruit. It was intended to estimate the weevil population by counts of capped blossom but time did not allow of more than four trees being counted so that no estimate could be made. The numbers on these trees varied from 800 to 2,000.

Preliminary Trials of New Materials.

During 1936 a small trial was carried out to test the suitability of certain substances for impregnating trap-bands. Observations were made of the effect on the bark. The following Table gives the results of this trial. These bands, being liable to damage the bark, had to be tried on worthless trees where there was very little Codling infestation, but notes on Codling and weevils are included where possible.

Treatment.	No. of bands.	Date of application.	Damage showing.	Remarks.
Lorol rhodanate	15	6.3.36	29.9.36	Codling Larvae found alive.
Lorol rhodanate +lubricating oil and petrol	15	6.3.36	29.9.36	,, ,,
Trichlorphenol in trichlorethylene	16	6.3.36	25.8.36	,, ,,
α-naphthol in trichlorethylene	15	6.3.36	25.8.36	,, ,,
β-naphthol in trichlorethylene	10	7.3.36	22.7.36	
α-chlor-β-naphthol in trichlorethylene	10	7.3.36	25.8.36	
β-chlor-α-naphthol in trichlorethylene	11	7.3.36	25.8.36	One Codling Larva. Dead.
	5	18.3.36	25.8.36	
	6	18.3.36	25.8.36	One Codling Larva. Dead.

The lorol rhodanate bands were tried last year and were repeated because the damage to the bark seemed less than with any other treatment. They were again the least harmful but definite injury to the bark did show by 29th September. The other treatments caused more severe injury some time before then, and all were considered unsuitable for use as impregnated trap bands.

This investigation has been carried out in collaboration with Imperial Chemical Industries Ltd., the majority of the chemically treated bands being supplied by them.

The writers are very greatly indebted to Mr. G. H. L. Dicker, B.Sc., for the valuable assistance he rendered in the experiments of 1936.

Summary.

1. An outline is given of the work at East Malling from 1919 to 1935 on trap bands for the control of Apple Blossom Weevil (*Anthonomus pomorum* L.) and Codling Moth (*Cydia pomonella* L.).

2. During 1936 corrugated cardboard bands treated with eight variations of three materials were used. None were as attractive to insects as untreated bands which is very different from the results obtained in previous years.

3. The degree of infestation of the orchard by *C. pomonella*, and the total population were estimated. From these figures it appears that untreated corrugated cardboard bands will trap approximately 50 per cent. of the larvae present in the orchard.

4. Counts of fallen fruit show that in this case *A. pomorum* did not cause any economic loss although the numbers of weevils present suggested a heavy infestation.

5. Preliminary trials of new impregnation materials are noted. All were found to cause injury to the bark.

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INSECTICIDES AND FUNGICIDES

SPRAY RESIDUE INVESTIGATIONS

I. DETERMINATIONS OF ARSENIC ON PEARS AND APPLES AND OF COPPER ON LOGANBERRIES

By H. SHAW

Among the many considerations involved in elaborating methods of pest and disease control on fruit trees, not the least important is that of spray residues. Common sense and the law alike demand that foodstuffs offered for human consumption must be tolerably free from noxious substances. Consequently, residues persisting on the fruit after spraying must not be of such nature or amount as to exceed the permitted limits or affect adversely the appearance of the fruit. Attention is thus immediately directed to the effect of sprays containing lead arsenate and other poisonous or otherwise objectionable materials.

In recent years, the increased use of lead arsenate in certain countries, particularly for the control of Codling Moth, has resulted in the retention on the fruit at picking time of residues so heavy as to necessitate the introduction of washing processes to render the fruit fit for consumption. While the position in England has not reached this stage, it has become necessary to resort to later applications of lead arsenate. As a result of this, it was essential to determine the latest time at which such sprays could be applied without raising the arsenical residue above the permitted amount of 0·01 gr. As_2O_3 per lb. (8).

While this present contribution was in preparation the report appeared of a very similar investigation carried out in France by Raucourt (7), who found that lead arsenate could be applied up to less than two months from picking time without exceeding the legal tolerance of 1 mg. As per Kg. of fruit.

A different, but scarcely less important, spray residue problem arises in the case of fruit, soft fruit in particular, destined for canning. Here, trouble has frequently resulted from the interaction of residual sulphur on the fruit with the metal of the can. This has given rise to swelling of the cans and to internal corrosion, with consequent spoilage of the contents (5, 11 *et al.*).

This problem was encountered in devising a combined spray for the control of Cane Spot and Raspberry Beetle on loganberries. Lime-sulphur gives a satisfactory control of the disease but is open to the objection mentioned above. Further, an unsightly deposit is very obvious on the earlier pickings. As an alternative, copper sprays were tried, and it thus became necessary to determine the residual copper on the fruit when picked.

The experiments here described were designed to elucidate these various points.

Arsenic.

Two series of determinations were carried out, one, in 1935, on Conference pears, the other, in 1936, on three varieties of apple, Early Victoria, Worcester Pearmain, and Edward VII, representative of the early, mid-season, and late apples respectively.

The pears were sprayed on 10th July, 1935, with lead arsenate (0·4% paste, 16% As_2O_3 content) + Lethalate Wetting Preparation (0·1%) by means of a " Cascade " hand-pump machine supplying a single nozzle at a pressure of about 200 lb. A good deposit in the eye and fairly even cover were obtained and good control of Codling Moth resulted (9). The weather was unusually dry for six weeks after spraying (five wet days, 1·34 in.), thence, for four weeks until picking time, there was very much more than average rainfall (4·89 in.). The fruit was picked on 10th September, ten weeks after spraying, and the windfalls were collected at the same time. The deposit then remaining was barely visible.

Two large samples were collected, the one of picked fruit and the other of windfalls, and from each of these, two samples, each weighing about 380 gm., were used for analysis.

In the case of the apples, a different procedure was followed. Single trees were sprayed with lead arsenate (0·4% paste) alone at approximately weekly intervals from 25th June to 30th July in the case of Early Victoria, and to 4th August in the case of Worcester Pearmain and Edward VII. The same " Cascade " machine was used and a good, though patchy, deposit was obtained. From the earliest spraying to the middle of August, there was much more than an average amount of rain (5·79 in. in seven weeks) including some very heavy showers. This had little obvious effect in reducing the density of the deposit. The fruit was picked at three widely different times, viz. Early Victoria on 30th July, Worcester Pearmain on 26th August, and Edward VII on 13th October. Judged by visual inspection when picked, the early variety was heavily coated with lead arsenate residue after all but the earliest application, the deposit on the mid-season variety ranged from light to fairly heavy and on the late variety from very light to moderate. There was no case in which the deposit was not visible.

Two samples from each treatment were taken. Because of the very different size of the varieties (the Worcesters and Edwards had been thinned), a compromise was effected between number of fruits and total weight taken for analysis. Of Early Victoria about fifteen fruits weighing 700-750 gm. were taken, of Worcester a similar number weighing 900-1000 gm., and of Edward VII about eight fruits weighing 1400-1500 gm.

The samples, pears and apples alike, were prepared for analysis according to standard procedure (2). In the early stages of digestion, very troublesome frothing occurred, especially in the case of Edward VII. This resulted in the loss of one replicate.

The arsenic was determined by direct comparison by means of the Gutzeit test with a standard arsenic solution containing 0·001 mg. As_2O_3 per ml. The results obtained are set out in Tables I-IV.

Table I.

Arsenical Residue on Conference Pears.

	Weight of sample.	Parts As_2O_3 per million.	Grains As_2O_3 per pound.
Picked Fruit	381 gm.	0·046	0·00032
		0·039	0·00027
,, ,, ...	383 gm.	0·039	0·00027
		0·052	0·00036
Windfalls	391 gm.	0·140	0·00098
		0·115	0·00081
,, ...	377 gm.	0·100	0·00070
		0·120	0·00084

Average As_2O_3 per lb. on picked fruit, 0·00031 gr.; on windfalls, 0·00083 gr.

Table II.

Arsenical Residue on Early Victoria Apples Picked on 30th July.

Date of application.	Weight of sample.	No. of fruits.	Parts As_2O_3 per million.	Grains As_2O_3 per pound.
25th June ..	735 gm.	15	1·44	0·0101
			1·44	0·0101
	744 gm.	15	1·60	0·0112
			1·42	0·0099
3rd July ..	709 gm.	15	1·49	0·0104
			1·30	0·0091
	715 gm.	15	1·21	0·0084
			1·11	0·0078
10th July ..	704 gm.	15	2·81	0·0197
			2·63	0·0184
	726 gm.	15	2·73	0·0191
			2·55	0·0178
17th July ..	732 gm.	15	1·58	0·0111
			1·65	0·0116
	713 gm.	15	2·78	0·0195
			2·78	0·0195
27th July ..	721 gm.	15	2·75	0·0193
			2·14	0·0150
	712 gm.	15	4·33	0·0303
			4·02	0·0281

Table III.

Arsenical Residue on Worcester Pearmain Apples Picked on 26th August.

Date of application.	Weight of sample.	No. of fruits.	Parts As_2O_3 per million.	Grains As_2O_3 per pound.
25th June ..	991 gm.	13	0·60	0·0042
			0·53	0·0037
	995 gm.	13	0·46	0·0033
			0·53	0·0037
3rd July ..	955 gm.	13	0·90	0·0063
			0·83	0·0058
	948 gm.	14	1·11	0·0078
			1·11	0·0078
10th July ..	942 gm.	12	0·32	0·0022
			0·35	0·0025
	973 gm.	13	0·75	0·0052
			0·81	0·0057
17th July ..	977 gm.	14	5·07	0·0355
			4·05	0·0284
	991 gm.	13	1·73	0·0121
			1·66	0·0116
27th July ..	862 gm.	12	2·04	0·0143
			1·79	0·0125
	927 gm.	13	1·00	0·0070
			1·14	0·0080
4th August ..	964 gm.	14	1·83	0·0128
			1·92	0·0134
	931 gm.	13	1·28	0·0089
			1·28	0·0089

TABLE IV.

ARSENICAL RESIDUE ON EDWARD VII APPLES PICKED ON 13TH OCTOBER.

Date of application.	Weight of sample.	No. of fruits.	Parts As_2O_3 per million.	Grains As_2O_3 per pound.
25th June ..	1481 gm.	8	0·49	0·0034
			0·49	0·0034
	1426 gm.	8	0·56	0·0039
			0·51	0·0036
3rd July ..	1476 gm.	8	1·16	0·0081
			1·07	0·0075
	1404 gm.	8	0·94	0·0066
			1·04	0·0076
10th July ..	1460 gm.	8	0·72	0·0051
			0·72	0·0051
	1459 gm.	8	0·81	0·0057
			0·90	0·0063
17th July ..	1450 gm.*	8	—	—
			—	—
	1410 gm.	8	1·72	0·0120
			1·56	0·0109
27th July ..	1463 gm.	9	1·35	0·0095
			1·50	0·0105
	1409 gm.	8	1·22	0·0085
			1·12	0·0079
4th August ..	1455 gm.	7	1·27	0·0089
			1·18	0·0083
	1458 gm.	7	1·22	0·0086
			1·22	0·0086

* Sample lost through excessive frothing.

The variation between the two samples from the same treatment, noticeable particularly in the case of the apples, is probably no greater than is to be anticipated. Cox (4) has found variations from 0·5 mg. to 15·0 mg. As_2O_3 per Kg. on individual apples from the same tree, while Percival and Potter (6), as a result of a very comprehensive investigation, have pointed out the large variations due to differences in the position of the fruit on the tree and to errors inherent in the methods of sampling and analysis. These variations are accentuated by variations in the size of the fruit. Samples made up of smaller fruits, having a larger surface area per unit of weight, would be expected to contain a larger amount of residue.

Since the increase in size of the fruit after spraying is probably a more important factor than weathering in the reduction of the amount of residue (7, 10), the rate of decrease will be highest when the fruit is growing most rapidly. The higher arsenic content of the pear windfalls as compared with the picked fruit, is doubtless due to the fact that the former were more mature and, therefore, larger at the time of spraying, and less growth took place subsequently.

From the above results, it appears to be unsafe to apply lead arsenate to apples and pears within six weeks of picking time, and only the latest varieties can safely be sprayed up to mid-July. This view is broadly in accord with the findings of Raucourt (7) and of Percival and Potter (6). In any case, quantities of arsenical residue approaching the permissible limit are so obvious to the eye as to render the fruit normally unsaleable.

COPPER.

Loganberries were sprayed on 25th June, 1935, with a wash containing derris powder (0·2%), a proprietary fungicide (0·1%) consisting of "copper oxychloride"

(90%) and sulphite pitch (10%), and Lethalate Wetting Preparation (0·1%). The spray contained 0·05% copper in an insoluble form. The same machine was used as in the experiments previously described. When dry there was no visible deposit other than derris powder on the fruit. There was no appreciable rain between the time of spraying and the commencement of picking on 10th July, but there was 0·9 in. during the three days 18th-20th July. The bushes were picked over at intervals of two or three days up to 31st July when they were finally stripped of all ripe fruit. All but the last picking consisted of berries of normal size as well as shape.

A duplicate representative sample of about 2 lb. was collected in the field at each picking and from each sample, 200 gm. was weighed out for analysis.

The sample was prepared according to prescribed procedure (1), and the copper estimated by the method of Callan and Henderson (3) using a tintometer to compare the samples with a standard copper solution containing 0·01 mg. Cu per ml. The results are shown in Table V.

TABLE V.

COPPER RESIDUE ON LOGANBERRIES SPRAYED ON 25TH JUNE.

Date of picking.	Parts Cu per million.	Grains Cu per pound.
10th July ..	8·5	0·060
	8·5	0·060
12th July ..	10·0	0·070
	10·0	0·070
15th July ..	10·0	0·070
	10·0	0·070
17th July ..	10·5	0·074
	10·0	0·070
19th July ..	9·5	0·067
	9·0	0·063
22nd July ..	8·0	0·056
	8·5	0·060
24th July ..	8·0	0·056
	8·0	0·056
26th July ..	9·0	0·063
	8·5	0·060
31st July ..	5·0	0·035
	5·0	0·035

The maximum amount of copper detected was 10·5 parts per million or 0·074 gr. per lb. There was not much falling off in the amount until the last picking of all on which only half of the above quantity was found.

It thus appears that no apprehension need be felt in applying copper sprays very shortly before picking time.

ACKNOWLEDGMENTS.

The author's thanks are due to Mr. W. Steer who was responsible for the spraying of the pears and the loganberries, and to Miss J. Annis and Miss M. E. Renwick who carried out the sampling of the latter fruit.

SUMMARY.

Arsenic has been determined on pears and apples, and copper on loganberries. The results indicate that " hard fruits " may safely be sprayed with normal amounts of lead arsenate up to six weeks before picking or up to mid-July in the case of later varieties,

while the application of copper sprays to loganberries as late as fifteen days before picking leaves only an insignificant residue of copper.

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INVESTIGATIONS ON THE PREPARATION OF FIELD-MADE WINTER PETROLEUM-OIL SPRAYS

A PROGRESS REPORT

By H. SHAW and W. STEER

Largely for reasons of economy of costs, there is at the present time a tendency among some growers to favour the use of home-made petroleum washes. In view of the lack of facilities in the field for carrying out any but the most simple processes of compounding materials, any such desire for home-made washes can be satisfied only when simple processes can be devised. In the case of mineral oil sprays, the only processes available have been the various modifications of the " two-solution " method (1, 2), all of which involve the troublesome and unpleasant weighing of caustic soda or measuring of soda lye, and the " tank-mixture " methods (3), which have not found favour in this country.

Thus there was an evident need for some emulsifying agent adaptable to field use to give, preferably, a miscible-oil type of concentrate which would yield the finished wash on dilution with water. By comparison with the " two-solution " methods, the maximum permissible cost of the emulsifier was of the order of 1s. 9d. per 100 gallons of wash (equivalent to 0·5% soap prepared from oleic acid, in the form of commercial brown oleine, and caustic soda).

On the basis of this price limitation and of general descriptions available, four emulsifiers*—Agral AX, Agral SR, Sulphonated Oil SKA, and Whitcol J—were selected for investigation. These could be used at concentrations up to 0·5%, thus giving, in the case of a winter oil used at 5%, a ratio of oil to emulsifier of 10 : 1.

Laboratory Trials.

5 ml. of the emulsifier was thoroughly mixed with 50 ml. of petroleum oil—Shell JD2—and the resulting mixture poured in a thin stream into 945 ml. of tap water, stirring vigorously the whole time.

1. *Agral AX* dissolved in the oil but, on pouring into water, very little emulsification took place. On adding 0·02% caustic soda, however, a very good emulsion immediately resulted.
2. *Sulphonated Oil SKA* behaved in a manner very similar to Agral AX. The emulsification was possibly slightly better but was still quite unsatisfactory.
3. *Agral SR*, an emulsifier widely used in the preparation of stock emulsions, was insoluble in the oil and therefore useless for the production of a miscible oil. On agitating a mixture of the emulsifier, oil, and water, some emulsification took place.
4. *Whitcol J* apparently dissolved completely in the oil, but on prolonged standing it separated out again. On pouring the freshly mixed preparation into water, with vigorous stirring, a white emulsion was produced. This was, however, far from perfect as there was a marked tendency for an oily layer to separate. Nevertheless, it was the nearest approach to a successful miscible oil.

* Products of Imperial Chemical Industries Limited.

Field Trials.

Although the laboratory tests of these emulsifiers had been only partially satisfactory, a small field trial was undertaken in order to obtain further information and, more particularly, to compare these emulsifiers directly with soap. In preparing soap emulsions of oils by the " two-solution " process, 1% soap, i.e. 1% of oleic acid and 0·15% of caustic soda, has commonly been used. It was considered that this might be an unnecessarily high concentration and lower concentrations—0·75% and 0·5%—were substituted in the trial. The other emulsifiers used were Whitcol J, Agral AX with caustic soda, and Agral SR.

The trial was carried out on apples and the spraying was done on 17th March, 1936. Five per cent. of the winter oil Shell JD2 was emulsified as described below and each mixture was applied to one tree of Lane's Prince Albert and one of Lord Derby. Both varieties were heavily infested with Red Spider eggs.

A. Four pints of oil were mixed with 12 oz. (0·75%) of oleic acid and poured into water containing 1·8 oz. (0·1125%) caustic soda. An excellent creamy emulsion resulted, and this was made up to 10 gallons with tap water.

B. This was prepared as above, but using 8 oz. (0·5%) of oleic acid and 1·2 oz. (0·075%) of caustic soda. The emulsion was not distinguishable from A.

C. Four pints of oil were well mixed with 8 oz. (0·5%) of Whitcol J and poured into 2 gallons of water. On diluting to 10 gallons a good, fairly stable, white emulsion was obtained. In later trials of this preparation some oily scum was formed.

D. Four pints of oil were mixed with 8 oz. (0·5%) of Agral AX and poured into water containing 0·32 oz. (0·02%) of caustic soda. On diluting to 10 gallons a yellowish emulsion was obtained from which the oil showed some tendency to separate.

E. Four pints of oil were poured into 2 gallons of water containing 8 oz. (0·5%) of Agral SR. On stirring and diluting to 10 gallons, a thin, oily, and generally unsatisfactory emulsion resulted.

The sprays were applied in warm, dry, sunny conditions. A hand-operated " Cascade " machine, supplying a single nozzle at about 250 lb. pressure, was used. Sprays A, B and D wet and spread excellently, but the wet film was not readily visible. Spray C gave very good wetting but did not run nearly so freely as the soap washes, and the wet film was milk-white and easily seen. Spray E wet well but gave the branches a greasy appearance as of oil standing on a wet surface.

Sprays A, B, D and E dried quickly, but C—the Whitcol J spray—required several hours. After twenty-four hours the trees were closely inspected. Treatments A, B and D were similar in leaving a good, even deposit of oil. Treatment C had left an obviously heavier deposit of oil in what appeared to be a perfect film. In treatment E the oil deposit was thin and very patchy, especially on Derby. Subsequent examinations gave the impression that the oil film was most persistent in the case of the Whitcol J emulsion. At no time was there any indication of damage with any treatment.

Red Spider nymphs began to appear on unsprayed trees about 4th May, and hatching was completed by about 25th May. On 15th May, when a great many eggs were still unhatched on the control trees, a few nymphs were found on the trees which had been sprayed with the Agral SR emulsion. None could then be found on any of the other sprayed trees. By 18th May very many mites had appeared on the controls, a few could be found on the Agral SR trees, but all the other sprayed trees were free from Spider.

On 26th May, when summer eggs were beginning to appear, the unsprayed trees were heavily infested and already showed severe Spider damage. No mites or damage could be found on any of the sprayed trees with the exception of those which had received the Agral SR emulsion.

No counts were made since the trial was not primarily designed as an experiment in Red Spider control and since it was clear that all but the Agral SR emulsion had given a complete control. Even the Agral SR emulsion gave a moderately good control.

During July the attack rapidly increased in intensity on the unsprayed trees and spread to the neighbouring sprayed trees till, by the end of July, mites and eggs were abundant even where a complete control of the winter eggs had previously been obtained. The mites were apparently spread from tree to tree by the wind since, on clean trees, they appeared first on the windward side.

Following upon the experience of the behaviour of the sprays described above, further investigations were undertaken to determine the effect of

(*a*) modifying the amount of mineral oil used in conjunction with 0·5% Whitcol J.
(*b*) reducing the concentration of oleic acid and caustic soda in the soap-emulsified washes.

(*a*) It was found that excellent, stable emulsions were readily obtained with concentrations of oil up to 3%, i.e. a ratio of oil to emulsifier of 6 : 1. With 4% or more of oil, a great deal of oily scum appeared and only on violent agitation was satisfactory emulsification effected. Up to 6% of oil could be used successfully when a power machine fitted with efficient agitators was employed. Under any conditions it is essential to secure efficient mixing of the oil and Whitcol by stirring, and it seems preferable to stir some water into the mixture before pouring it into the tank.

(*b*) As a result of the preliminary tests with soap emulsions, 0·5% soap was substituted for the customary 1% in the routine farm-spraying during the winter of 1936-7, and proved very satisfactory. The concentration of soap was still further reduced in a series of small-scale field trials. 0·25% soap, i.e. 0·25% oleic acid and 0·0375% caustic soda, used with 6% oil gave a stable emulsion quite as good as that using 0·5% soap. On account of the hardness of the water it was impracticable to reduce the caustic soda below 0·0375% (6 oz. per 100 gallons) but reduction of the oleic acid to 0·15% gave an emulsion only slightly inferior to those containing higher concentrations. A small amount of oil separated on standing but was easily re-incorporated. This 0·15% soap spray wet well and showed less tendency to run off than emulsions prepared with higher concentrations of soap. The wet film was white and easily seen during spraying and a good, even deposit of oil remained.

A quick and easy method of preparing the soap-oil emulsion in the field comprises ladling out flaked caustic soda from a biscuit tin (kept closed when not in use) by means of any suitable receptacle just large enough to hold the required weight. The caustic soda is then put into the spray tank into which water from the tap is running rapidly. The oil and oleic acid are stirred together in some such vessel as a 10-gallon drum from which the top has been removed, and poured into the spray tank when it is about three-quarters full. Emulsification occurs instantly and water is allowed to run in until the tank is quite full.

At current prices (spring 1937) the cost of a 6% oil spray (equivalent to 7·5% of a proprietary emulsion containing 80% oil) is approximately 7s. 6d. per 100 gallons whether 0·5% Whitcol J or 0·5% soap is used as emulsifier.

From the foregoing account it is evident that, despite its apparent drawbacks, the soap-emulsification method can be so carried out as to compare favourably with

other available methods. In view of the possibility of reducing the soap concentration below 0·5%, this method possesses a definite advantage over others on a cost basis.

Summary.

0·5% Whitcol J was found to be a satisfactory emulsifier for field-made winter petroleum washes containing up to 3% oil or up to 6% when efficient power agitation was employed. In the oleic acid-caustic soda " two solution " method of emulsification, the oleic acid was successfully reduced to 0·15% and the caustic soda to 0·0375% (i.e. an equivalent amount making due allowance for the hardness of the water).

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OBSERVATIONS ON CODLING MOTH *(CYDIA POMONELLA* L.*)* IN 1936

By W. STEER

In last year's Annual Report some preliminary observations on the Codling Moth were described in a progress report (1). The present paper deals with the continuation of this investigation.

Emergence of the Moths.

Larvae collected during the summer of 1935 were kept under observation in cages in a manner similar to that adopted in the 1934-5 experiments (loc. cit.). Daily records (see Fig. 1) of the numbers of moths which eventually appeared show that emergence began somewhat earlier than in 1935 (on 18th May as compared with 28th May) but, again, most of the moths appeared during June. The moths emerged at any time during the day but never during the night.

Fig. 1 clearly shows that day to day fluctuations in the emergence curve were due to changes in temperature. The number of hours when the temperature exceeded 60° F. (as shown by thermograph records) is plotted against the number of moths which emerged from day to day.

The moths were all derived from mature larvae collected in sacking bands in the preceding year. As these larvae had been collected at weekly intervals in 1935 to ascertain the period during which larvae leave the fruits to seek winter shelter, the various batches could conveniently be kept separate. The emergence period of the moths could thus be studied in relation to the period during which the larvae left the fruit in the preceding summer. Most of the early emergencies occurred in the cage containing the earliest of the 1935 batches (collected up to 8th August). On the whole, however, there was no connection between the dates on which the larvae left the fruit and the dates of emergence of the moths (see Fig. 2). A few of the latest batch (collected as larvae 5th-26th September) actually emerged as soon as those of the first batch.

As so little Codling occurred at East Malling in 1936, field notes on the incidence of the moth were necessarily scanty. Such observations as could be made suggest that most of the moths emerged in June but that some emerged in July. Thus moths emerged on 4th, 17th, 21st, 24th and 25th June from pupae collected in the field on various dates from 28th May to 22nd June, and on 7th July moths emerged from two pupae collected on 6th July. A few were caught in treacle traps as late as 17th July.

All the eggs found in the field could be ascribed to moths which emerged in June and early July. If any moths emerged under natural conditions in May they probably perished before suitable weather for egg-laying occurred.

Many empty pupal cases and a few pupae were found (chiefly in the pith of bamboo canes) in a cordon apple plantation at Swanley, Kent, on 16th June. From pupae collected there moths emerged on various dates from 17th to 21st June.

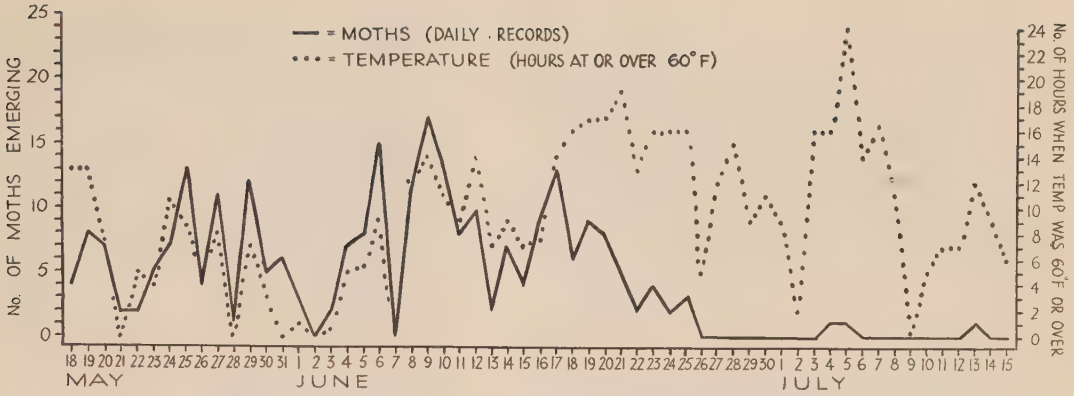
— = MOTHS (DAILY RECORDS)
••• = TEMPERATURE (HOURS AT OR OVER 60° F)
No. OF MOTHS EMERGING
No. OF HOURS WHEN TEMP WAS 60° F OR OVER
MAY
JUNE
JULY

FIG. 1. Emergence of Moths in 1936.

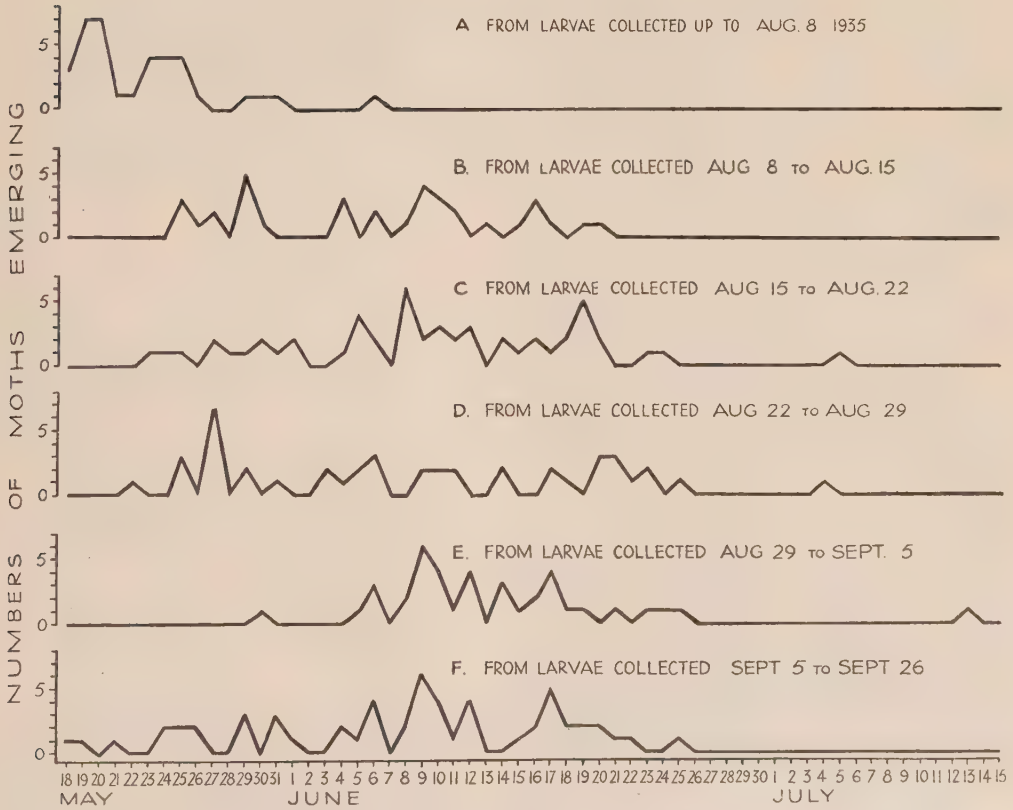
A FROM LARVAE COLLECTED UP TO AUG. 8 1935
B. FROM LARVAE COLLECTED AUG 8 TO AUG. 15
C FROM LARVAE COLLECTED AUG 15 TO AUG. 22
D. FROM LARVAE COLLECTED AUG 22 TO AUG 29
E. FROM LARVAE COLLECTED AUG 29 TO SEPT. 5
F. FROM LARVAE COLLECTED SEPT 5 TO SEPT 26
NUMBERS OF MOTHS EMERGING
MAY
JUNE
JULY

FIG. 2.

Emergence of Moths in 1936 from periodic collections of mature larvae made in the previous summer.

Egg Laying.

It is generally agreed that the moths require calm evenings and a temperature above 60° F. for egg laying. Assuming this to be so, it can be shown that there were few suitable days on which egg laying could have occurred.

Fig. 3 shows the incidence of warm calm weather at East Malling from 18th May to 31st July. The heavily shaded areas represent those portions of the day when the force of the wind was below about 2 Beaufort (as recorded by an anemobiagraph) whilst the lightly shaded areas indicate periods when the temperature (recorded by a thermograph) was above 60° F. It will be seen that conditions favourable for egg laying were largely confined to a few short periods (Table I).

Table I.

Chief Periods of Expectation of Egg Laying (1936).

1	About five days	June 8-12
2	About four days	June 17-20
3	About seven days	June 23-29
4	About four days	July 5- 8
5	About six days	July 25-30

Field observations agree well with these calculations. Notes made on the incidence of eggs (in various stages of development) and of larvae are tabulated below, together with an indication of the probable periods during which the eggs were laid. " Red ring " eggs are those which have reached such a stage of development that the embryo within the egg may be seen as a faint red ring, a stage reached, usually, in about three days. A day or two before hatching the head and thoracic plate of the larva appear as a conspicuous black spot and the term " black spot " is therefore employed to denote eggs which have reached this stage.

Table II.

Date and stages found.	Probable period* during which eggs were laid.
June 11, newly laid eggs	June 8-11
June 21, " red ring " eggs	June 17-20
June 21, larvae	June 8-12
June 26, newly laid and " red ring " eggs	June 23-29
June 29, newly laid eggs	June 23-29
June 29, hatched eggs and larvae	June 17-20
June 30, " red ring " and " black spot " eggs	June 23-29
June 30, hatched eggs and larvae	June 17-20
July 6, hatched eggs and larvae	June 23-29
July 7, larvae	June 23-29
July 10, hatched eggs and larvae	June 23-29
July 10, " red ring " eggs	July 5- 8
July 14, " red ring " eggs	July 5- 8

* The dates shown in the right-hand column are the periods of expectation of egg laying (see Table I) indicated by the data of Fig. 3.

The eggs found on 11th June were laid by moths confined in muslin sleeves. No eggs laid under natural conditions were found in the Station's plantations till 21st June.

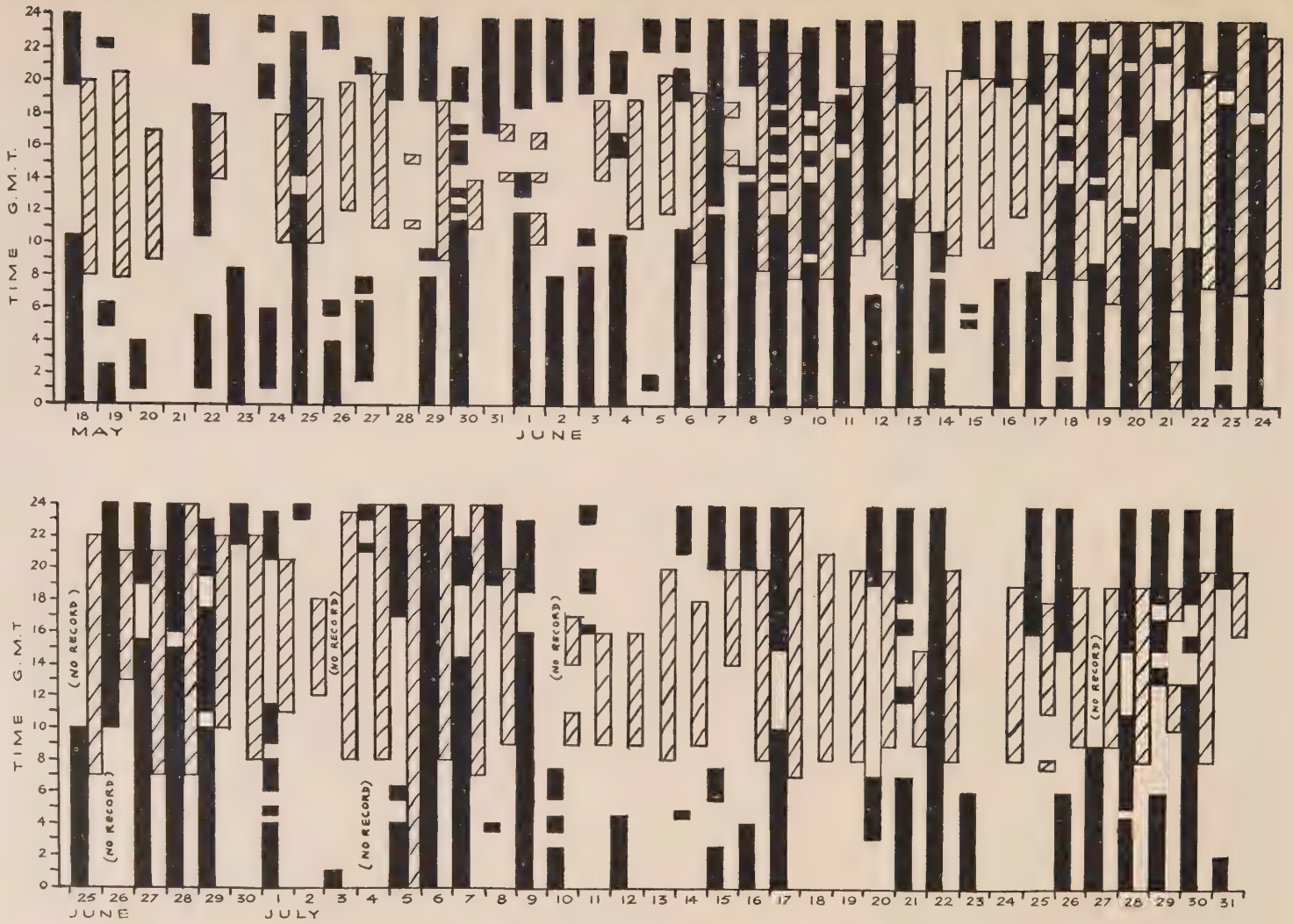

FIG. 3. Hours of temperature above 60° F. and hours of wind below 2 Beaufort from 18th May to 31st July, 1936.

■ = wind below 2 on Beaufort scale.

▨ = temperature 60° F. or over.

Most of the eggs appear to have been laid late in June and early in July. Egg laying in a Swanley plantation occurred at much the same time. Only one egg was found there on 16th June in the course of a careful search. On 16th July plenty of attacked fruits, hatched eggs and newly hatched larvae were found (which suggests that numerous eggs were laid late in June and early in July) together with several eggs in various stages of development.

Incubation Period.

To obtain a supply of eggs, moths were placed in muslin sleeves on apple shoots on various dates from 8th to 19th June, from five to ten moths being placed in each sleeve. Eggs were laid freely on leaves and fruits. They were examined daily and the first appearance of the " red ring " and " black spot " stages and of hatching were recorded. The results given by six of the sleeves are set out in Table III, which shows that Codling Moth eggs can (at any rate under warm weather conditions such as those which prevailed whilst this experiment was in progress) hatch within seven to ten days.

Table III.

Rate of Development of Codling Moth Eggs.

Date eggs laid.	Dates on which were first found			Minimum incubation period observed.
	" Red Ring."	" Black Spot."	Hatched eggs.	
1 June 8-11	June 15	June 20	June 21	10 + days
2 June 16	June 18	June 22	June 23	7 days
3 June 17	June 21	June 24	June 26	9 days
4 June 18-19	June 21	June 25	June 26	7-8 days
5 June 18-19	June 21	June 26	June 27	8-9 days
6 June 21	June 24	June 27	June 27	6 + days

Entry into the Fruit.

Although eye entry appeared to be rather more prevalent on apples in 1936 than in the preceding year, it was, nevertheless, found less commonly than side entry. Eye entry was commoner on some varieties than on others. About half the entries on some cordon trees of the variety Egremont Russet were found to have been effected through the eye. Eye entry was much commoner than side entry on Allington, but on most of the varieties examined (including Worcester, Edward VII, Cox, Blenheim, Cutler Grieve and Macintosh Red) side entry was the general rule.

Eye entry was again found to be the commoner mode of attack on pears.

Where hail damage had occurred it was found that the newly hatched larvae often showed a preference for hail spots when beginning their attack on the fruits. Thus on 30th June small larvae were observed entering fruits of Cox at the small corky areas (usually not more than about 2 mm. in diameter) caused apparently by hail which fell early in June.

The Second Generation.

The period during which the larvae matured and left the fruit was determined by making weekly collections of larvae from sacking bands placed around the stems of apple

trees (see Fig. 4). Two pupae were found in the bands when the first (7th August) collection was made, and from one of these a moth emerged on 27th August. Two moths also developed from the batches of larvae collected up to 13th August ; these emerged on 27th and 28th August.

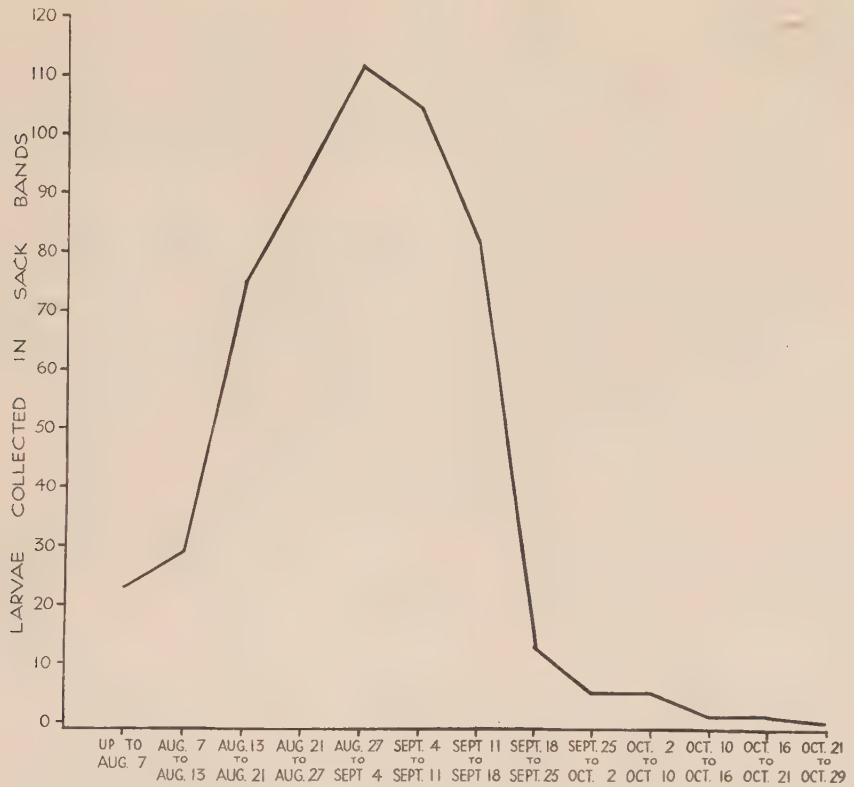

Fig. 4. Showing periods during which Codling Moth larvae left the fruit to seek shelter in sack bands in 1936.

In the field, also, evidence of the occurrence of a partial second generation was obtained. Newly attacked fruits, and fruits containing small larvae, were found whilst picking Worcesters on 12th and 24th September. Fruits of Cox, examined in the middle of October, also bore damage which could only be ascribed to second generation larvae. A few moths were caught in bait pans early in September.

Control Measures.

A. Worcester Pearmain.

A spraying trial was carried out on Worcester Pearmain to ascertain the correct time of application and the minimum necessary number of sprayings of lead arsenate, and to determine whether the addition of an oil emulsion increases the efficiency of a lead arsenate spray.

The details of the various treatments were as follows :

	May 25.	June 23.	July 10.
Controls	LS.	LS.	—
Calyx spray only	LS.**A.**	LS.	—
1st cover wash only	LS.	LS.**A.**	—
1st cover wash only	LS.	LS.**A.Oil**	—
2 cover washes	LS.	LS.**A.**	**A.**
2 cover washes	LS.	LS.**A.**	**A.Oil**

LS. *Lime-sulphur.* S.G.1·3 ; polysulphide sulphur content approximately 20% (weight/weight). Used at 1%.

A. *Lead arsenate.* Paste ; 15-16% (by weight) arsenic pentoxide. Used at 0·4%.

Oil. *Refined petroleum oil.** Emulsified with sulphite lye ; used in the form of a 67% emulsion at a concentration (1·5%) sufficient to give 1% of oil in the spray.

All the sprays were applied under good weather conditions by means of a small power machine supplying two Turnbull double nozzles (fitted with 7-hole swirl plates and No. 1 discs) at a pressure of about 300 lb. The trial was carried out on four rows of trees, six trees (in two plots of three trees each) being allocated to each treatment.

The results of counts made of the whole of the crop are shown in Table IV.

TABLE IV.

Spray Treatment.	% fruits attacked by Codling Moth larvae.	Average number of fruits per tree.
Controls LS. .. .. LS. —	2·4	512
Controls (duplicate series)	2·4	721
Calyx spray LS.A. .. .. LS. —	0·8	613
One cover only LS. .. .. LS.A. —	0·5	677
One cover only LS. .. .. LS.A.Oil —	0·03	262
Two covers LS. .. .. LS.A. A.	0·3	626
Two covers LS. .. .. LS.A. A.Oil	0·5	524

As the infestation was so low it is difficult to draw definite conclusions from the above figures.

The calyx spray (25th May) reduced the attack considerably, but it would be unsafe to conclude that such a spray would, by itself, satisfactorily control a severe infestation.

* For a complete specification of this oil, see Kearns, Marsh and Martin, Long Ashton Res. Sta. Ann. Rep., 1934, p. 12.

First cover wash. Although it cannot be concluded from these figures that a late June spray is much more effective than a calyx spray, the field observations made on egg laying and hatching are in favour of such a conclusion. The addition of petroleum oil emulsion to the first cover wash (23rd June) gave the best control of Codling but caused serious fruit drop.

A second cover wash (10th July) did not improve the result given by that of 23rd June. Two possible explanations of this can be suggested :

1. Most of the Codling on these plots hatched late in June or early in July and could therefore be killed by the first cover wash.

2. Each of the sprays applied on 10th July left a poorer deposit than any of those applied on 23rd June.

B. Cox's Orange Pippin.

In an insecticide-fungicide trial on Cox (reported elsewhere in this Annual Report, p. 267) the effect of adding lead arsenate to the normal second post-blossom ("three weeks") Scab spray was tested (Table V).

TABLE V.

EFFECT OF ADDITION OF LEAD ARSENATE PASTE (0·4%) TO THE SECOND POST-BLOSSOM SCAB SPRAY (16TH JUNE).

	% fruits attacked by Codling Moth larvae.		
	Arsenate omitted.		Arsenate included.
Lime-sulphur 1%	2·1	average 1·2	0·8
Lime-sulphur 1%	1·5		0·8
Lime-sulphur 1% + "Lethalate" 0·05%	0·5		0·8
Bordeaux Mixture 2 : 10 : 100	0·6		0·3

The infestation was very low and somewhat unevenly distributed, but the figures, taken in conjunction with those of Table IV, suggest that lime sulphur-lead arsenate is somewhat less effective used at three weeks than at four weeks after petal-fall. It could not be shown that the addition of a spreader improves the degree of control given by a lime-sulphur and lead arsenate spray.

CONCLUSIONS.

At East Malling two seasons' records show that egg laying begins in the middle of June, reaches a peak in the latter part of June and early July, and may continue till after the end of July. Larvae occur from the third week in June onwards.

From a consideration of these facts and of the results of the 1936 spraying trials it would appear that lead arsenate (preferably in combination with lime-sulphur) should be applied late in June (say 23rd-30th June) and again, if possible, towards the middle of July (say 10th-15th July).

For a moderate attack the first of these sprayings is, by itself, likely to prove adequate.

Where severe attacks habitually occur the petal-fall Scab spray should (until more definite information is available) contain lead arsenate. Two cover washes (late June and mid-July) should also be applied.

When using lead arsenate late in the season it should be borne in mind that early varieties, such as Emneth, should never be sprayed after the end of June. Only very late varieties, such as Edward VII, can be sprayed with lead arsenate in the middle of July without some risk of getting a troublesome deposit on the fruits (see East Malling Research Station Annual Report for 1936 (1937), pp. 240-5). When spraying as late as the middle of July, therefore, some other insecticide such as Derris should be used in place of lead arsenate.

Summary.

An account is given of some observations made at East Malling in 1936 on the habits of the Codling Moth (*Cydia pomonella* L.).

Most of the moths emerged in June. Eggs, which hatched in seven to ten days, were laid from mid-June onwards, but chiefly during the latter part of June and early in July.

Larvae began to attack the fruit towards the end of June, entering pears almost always through the eye and apples mostly at the side.

Evidence of a partial second generation was obtained; moths emerged late in August and small larvae were found attacking apples in September.

The results of spray trials carried out on apples were not conclusive as very little Codling occurred, even on unsprayed trees. They suggest, however, that the first cover wash of lead arsenate should be applied late in June. Where severe attacks occur lead arsenate should also be applied at petal-fall and, where it can safely be done, in the middle of July.

Reference.

(1) Steer, W. "Observations on Codlin Moth in 1935." E. Malling Res. Sta. Ann. Rep. for 1935 (1936), 186-90.

FIELD TRIALS IN 1936 OF THE FUNGICIDAL AND PHYTOCIDAL PROPERTIES OF CERTAIN NEW CHEMICAL PREPARATIONS

A PROGRESS REPORT

I. FUNGICIDAL PROPERTIES

By M. H. MOORE and H. B. S. MONTGOMERY

INTRODUCTION.

The work done in this connection in 1934 and 1935 has already been published as a progress report (2). In 1936 the fungicidal properties of the two standard fungicides, lime-sulphur and Bordeaux mixture, were compared with those of three new sulphur preparations and one new copper preparation. Nine-year-old bush apple trees of Worcester Pearmain, Edward VII, Allington Pippin and Newton Wonder, all on No. IX rootstock, were available for spraying trials: these comprised a plot of 124 trees, nominally 30 of each variety, planted in " latin squares ".

THE TRIAL.

In order to compare the sprays on the most equal basis, they were diluted to contain equivalent amounts of the fungicidally-active principle, the standard being determined by the known reactions of lime-sulphur and of Bordeaux mixture at certain dilutions. Thus, the sulphur sprays were diluted to contain approximately as much sulphur in elementary form (0·2%) as there is sulphur in polysulphide form in lime-sulphur (S.G. 1·3; polysulphide sulphur, 25% weight in volume) at 1·0% by volume—the nearest possible standard of comparison in this instance. The diluted copper sprays each contained 0·075% copper, which is the amount present in a Bordeaux mixture containing 0·3% copper sulphate.

The sprays were each applied at four periods in the growth of the trees:

(*a*) green-bud (27th April),
(*b*) pink-bud (6th May),
(*c*) petal-fall (27th May),
(*d*) three weeks after (*c*) (20th June).

A hand-operated, barrel-type machine, developing about 300 lb. per sq. in. pressure, and supplying a lance with a " Broadway " double nozzle fitted with $\frac{3}{64}$ in. discs, was used. A hessian screen arrested spray-drift.

The following sprays were compared:

Those containing sulphur.

(i) Lime-sulphur (specification as above), **1% pre- and post-blossom,** with " Lethalate " Standard Wetting Preparation (see this Annual Report, p. 269), **0·05% pre- and post-blossom,** as spreader.

(ii) " Microsul ", a 40% " micronized "-sulphur preparation, dispersed with sulphite lye, and containing an aqueous solution of methyl cellulose as spreader. Particle size ; 4-5 μ. Used at **0·5% pre- and post-blossom.**

(iii) " Sulsol ", a 42% (nominal 40%) colloidal-sulphur preparation, S.G. about 1·4, dispersed with 20% sulphite lye and containing a small proportion of other auxiliary materials. Particle size ; 60-90% by weight, not greater than 2 μ. Used at **0·5% pre- and post-blossom.**

(iv) " RD 4367 ", a 40% colloidal-sulphur preparation, containing 4% of dispersing agent and 10% of spreader ; also a small proportion of other auxiliaries. Particle size ; the greater part of the material is in the form of particle-aggregates ranging from 8-20 μ. Used at **0·5% pre- and post-blossom.**

Those containing copper.

(v) Bordeaux mixture, 0·3% copper sulphate and 0·9% hydrated lime ; i.e. the formula **3-9-100 pre- and post-blossom.**

(vi) " Bouisol ", a colloidal-copper preparation containing 15·5% (nominal 15%) of copper in the form of a complex mixture of basic salts, mainly chloride and sulphate, dispersed with 20% sulphite lye. The ionic copper amounts to no more than 20 mg. per litre. Used at **0·5% pre- and post-blossom.**

The " buffer " trees, on the headlands at each end of the plot, were given the normal routine spray-treatment, viz. lime-sulphur, **2·5% pre-blossom** and **1% post-blossom.** To this, " Lethalate " Standard Wetting Preparation was added, at 0·05% pre- and post-blossom, as spreader. It was thus possible to compare the merits of the weak pre-blossom lime-sulphur spray with those of the stronger one (see this Annual Report, p. 269), though this comparison does not, of course, fall strictly within the limits of the statistically-planned trial.

Nicotine at 8 oz. per 100 gal. was added to each spray at petal-fall to control Sawfly. The control trees, however, were not sprayed at any period.

General Observations.

All sprays wetted poorly before blossom, but afterwards there was distinct improvement, especially with lime-sulphur, to which a spreader was added.

Weather Conditions.

Good weather favoured the application of sprays at each period, but the summer weather generally was very wet and suitable for Scab-development. May, however, was a " dry " month, during which the progress of infection was temporarily checked.

Spray-Injury.

The following observations were made on 3rd June : The " rosette " leaves of Newton Wonder showed marginal burning where lime-sulphur was applied at 2·5% pre-blossom. There was no injury from the 1% solution used pre-blossom ; used at petal-fall, however, this spray caused slight spotting on the young Newton leaves. Slight leaf-burn was present on Allington and Newton sprayed with the Bordeaux mixture, while Allington leaves sprayed with Bouisol were covered in minute, circular, red spots, each representing a tiny patch of burnt tissue. These spots were seen also on Newton

and Edward, though not nearly to the same extent, while on Worcester they were rare. No injury was seen on any trees sprayed with the three new sulphur preparations.

Further observations were made on 23rd June, three days after the final spray-application :

A very uncommon type of injury was present on all varieties sprayed post-blossom with lime-sulphur (1%). The leaves towards the centre of the current year's extension growth showed inter-veinal, rather bright-red patches of burnt tissue ; also tiny, scattered spots of similar hue. Trees sprayed with the other sulphur-preparations still showed no injury. A noteworthy point was the absence of leaf-drop on Newtons on this plot : elsewhere on the Research Station, Newtons sprayed post-blossom with lime-sulphur at 1% showed some leaf-drop at this period. Probably the explanation is to be found in the type of growth obtained. These young Newtons in the spraying trial were noticeably " harder ", and the growth was sturdy and not lush, while those on which leaf-drop was observed had grown more rapidly and produced more " wood ", suggesting, perhaps, the greater availability of nitrogen.

Very severe fruit-russeting and some leaf-burn was seen on trees sprayed with the copper-containing sprays. This all resulted from sprays applied prior to the second post-blossom application.

By 3rd July, all copper-sprayed trees, irrespective of variety, were showing very severe injury, leaf-burn, defoliation, and fruit-russeting. Interesting differences between the types of injury caused respectively by the Bordeaux mixture and by Bouisol were observed. These differences on the fruit are illustrated in Fig. 1. It will be seen that the Bordeaux mixture caused a diffuse, reticulate type of russet while Bouisol burnt the skin in small, dark, bullate, " islands ", similar to those caused by copper-lime dust in wet or dewy weather. The " islands " arise probably where minute, suspended particles of " copper " come to rest on the fruit, ultimately setting up tiny, localized areas where soluble copper is concentrated above the danger-point to the skin. The even distribution of these tiny, burnt areas is really a tribute to the excellent dispersion of the particles of copper in that form of spray. As the season progressed, the distinction between the two forms of burning disappeared, the mature fruits in either case being diffusely russeted and, some, severely cracked. On the leaves, Bordeaux-injury was seen as large or small, irregular, reddish blotches, while that caused by Bouisol varied somewhat with the host-variety—tiny, circular, reddish spots on Allington, larger and more blotchy, purplish spots on Worcester. The injury recorded on 3rd July was probably the combined effect of the petal-fall and second post-blossom applications ; it steadily increased to a maximum by the end of the month.

Scab.

Infection was becoming severe on the leaves of control trees during the flowering period. By early June, however, there seemed to be much less, so presumably some of the infected leaves had dropped. Towards the end of June, after a prolonged period of wet weather, infection was flourishing on the fruits and leaves of control trees, and of some of the sprayed trees. The disease developed steadily throughout the season, and the mature fruits from control trees of Allington and Newton were nearly all unsaleable. Worcesters were not so badly affected, while Edwards, as usual, were free from Scab.

Insect Pests.

Only very light attacks of Codling Moth, Sawfly and Red Spider occurred ; none of these was worth recording.

Recording.

The Worcester fruits were picked on 3rd September, the Allingtons and Newtons on 16th and 17th September and the Edwards on the 20th October. Excepting Edwards, which were Scab-free, all were graded for Scab into categories, and the " Scab-equivalents " were computed on the lines of the method described elsewhere (1).

Results.

The data are tabulated on page 263. Each value, with few exceptions, is an average for four similar trees.

Discussion of Results.

The Crop. If, for the moment, the host variety is disregarded, and the average crop per tree for each treatment is considered, it will be seen that Bouisol, and each of the lime-sulphur treatments, caused appreciable fruit-drop. In justice to Bouisol it must be emphasized that the spray was made up considerably stronger than is recommended by the proprietors. This was deliberately done in order to compare the colloidal copper with a weak Bordeaux mixture of equivalent copper content. Evidently, the colloidal form is the more potent phytocide, and it remains to be seen whether it is fungicidally effective and non-phytocidal at a lower concentration. Rather more fruit-drop occurred with pre-blossom lime-sulphur at 2·5% than at 1%, which suggests that, while the 1% *post*-blossom spray was undoubtedly responsible for most of the fruit-drop, yet the stronger *pre*-blossom spray also had a share in this, probably through some slight, undetermined injury to the unopened flower-trusses. Although positional variation may be a factor in this instance (the trees sprayed pre-blossom with the stronger spray were all on the headlands), some support for the suggestion was found in another trial (see p. 271 of this Annual Report) on Cox's Orange Pippin. Neither the Bordeaux mixture nor any of the three new sulphur preparations caused fruit-drop.

Turning now to the individual varieties, it will be seen that Allington Pippin most truly reflects the general position, probably because it cropped better and more consistently than the other varieties ; it is, therefore, a good " indicator " variety in this respect. Newton, a rather " shy " cropper, is not a good " indicator " variety, for it shows the greatest variation from average, particularly as regards the " buffer " trees. Here, the weaker pre-blossom lime-sulphur spray appears to have caused slight fruit-drop while the stronger has not !—evidently an unreliable result. Again, Bouisol appears to have caused no fruit-drop on Newton : it is more likely, however, in the light of the results shown by other treatments on this variety, that the figure for picked fruits on the controls was depressed in some way at present unexplained.

Scab (*Venturia inaequalis* Cooke (Wint.)). Scab was not present on Edward fruits so they were not graded. Worcesters were only lightly infected, but Newton and Allington control trees were severely attacked. All spray-treatments, except Microsul, gave very good control ; lime-sulphur was outstanding, the stronger pre-blossom spray being rather more effective than the weaker. On Cox's elsewhere on the Research Station, little difference was found between them in this respect (see this Annual Report, p. 272). The copper-containing sprays allowed little Scab to develop, but they were not safe because of the leaf-burn and fruit-russeting they caused. The respective colloidal sulphurs were satisfactory, though significantly* less effective than lime-sulphur, and

* The figures were subjected to statistical analysis by Miss J. L. Edgar, to whom the writers are greatly indebted.

Treatment.	Worcester.			Edward.			Allington.			Newton.			Average for Treatment (all varieties).	
	No. of Trees.	Average Fruit picked.	Average Scab-equivalent.	No. of Trees.	Average Fruit picked.	Average Scab-equivalent.	No. of Trees.	Average Fruit picked.	Average Scab-equivalent.	No. of Trees.	Average Fruit picked.	Average Scab-equivalent.	Fruit picked.	Scab-equivalent.
Lime-sulphur (1% throughout) with "Lethalate"	4	11·5	0·9	4	24·3	—	4	122·5	2·4	4	24·5	0·9	46	1·4
"Microsul" (0·5%)	4	34·3	5·1	4	51·0	—	4	159·0	25·1	4	53·3	11·2	74	13·8
"Sulsol" (0·5%)	4	35·8	0·7	4	37·0	—	4	199·8	6·1	4	30·0	2·7	76	3·2
"RD 4367" (0·5%)	4	38·8	2·6	4	29·5	—	4	164·0	7·2	4	44·3	1·7	69	3·8
Bordeaux mixture (0·3% copper sulphate; 0·9% hydrated lime)	4	31·3	0·3	4	27·8	—	4	133·0	5·6	4	53·3	1·1	61	2·3
"Bouisol" (0·5%)	4	2·0	0·0	4	21·0	—	4	43·5	3·0	4	37·0	0·8	26	1·3
Controls (unsprayed)	4	**36·0**	**9·7**	4	**41·3**	—	4	**158·0**	**53·1**	4	**32·3**	**34·8**	**67**	**32·5**
Lime-sulphur (2·5% pre-blossom, 1% post-blossom) with "Lethalate". **On "buffer" trees only**	3	8·7	0·0	2	18·0	—	4	54·5	0·2	2	36·0	0·0	29	0·1

more expensive to use. They caused no injury, however, and are worth further trial as post-blossom sprays following lime-sulphur used pre-blossom. Although the use of Microsul reduced infection by rather more than one-half, this preparation did not compare favourably as a fungicide with the other sulphur-containing sprays. Its reduced efficiency may possibly be conditioned by its being in crystalline, and not amorphous, form, in consequence of its being produced by a grinding, as distinct from a precipitation, process.*

Summary.

Four new fungicides, one containing copper and three containing sulphur, were compared on a field scale with the standard fungicides, Bordeaux mixture and lime-sulphur. The trees sprayed were nine-year-old Worcester Pearmain, Edward VII, Allington Pippin and Newton Wonder, all on No. IX layered rootstock. Four applications of each spray were made, two pre- and two post-blossom. Each gave satisfactory control except " micronized " sulphur (" Microsul ") which, at 0·5%, however, reduced the amount of infection, compared with that on control trees, by about one-half. Lime-sulphur was more effective than either of two colloidal sulphurs; at 2·5% pre-blossom it was slightly more efficacious than at 1% pre-blossom ; at 1% post-blossom it caused fruit-drop, while each of the colloidal-sulphur preparations, at 0·5%, was safe.

Each of the copper-containing sprays caused leaf-burn and fruit-russeting, a colloidal form (" Bouisol "), at 0·5%, being more potent in this respect than Bordeaux mixture at 3-9-100, as well as causing severe fruit-drop.

Control trees of Allington and Newton became severely Scab-infected ; those of Worcester were only lightly infected, and those of Edward VII remained Scab-free.

II. PRELIMINARY PHYTOCIDE TESTS

By H. SHAW

The tests were carried out on single branches of Cox's Orange Pippin as in 1935 (2) except in the case of the Cottonseed Oil-Bordeaux mixtures. These latter were applied to one young tree each of Worcester Pearmain, Bramley's Seedling, Lane's Prince Albert and Cox's Orange Pippin, using a knapsack hand-spraying machine. In all cases spray damage was assessed by periodic inspection. No attempt was made to estimate the fungicidal value of the sprays.

General Remarks and Conclusions.

Every form of copper applied to Cox's Orange Pippin caused more or less severe damage at all concentrations down to 0·1% Cu and, in one case, down to 0·025% Cu. It should be mentioned that 1936 was a season notable for the severity of copper damage.

The oil-shirlan preparation at 1% caused slight russeting of the fruit, and 2% or 1% of the 10% 1-chloro-2-naphthol miscible oil caused rather more severe damage.

The remaining products, i.e. 25% tetramethylthiuram disulphide dispersion, 20% ammonia-shirlan, copper-8-hydroxyquinoline (20% base) and 10% Brilliant Green on bentonite, were all quite safe at concentrations up to 1%.

* The writers are indebted to Dr. H. Shaw for this suggestion.

Product.	E.M.R.S. Ref. No.	Concentration (by weight).	Remarks.
Applied on 25th May.			
(1) Burgundy paste	3546	1-45 (0·2% Cu)	Easily mixed; good suspension; moderate wetting. Severe damage (fruit cracked and russeted; leaves burned).
(2) do.	do.	1-90 (0·1% Cu)	As (1).
(3) Cuprous oxide-Goulac paste	3547	1-85 (0·2% Cu)	Mixing, etc., as (1). Very severe damage (fruit- and leaf-drop).
(4) do.	do.	1-170 (0·1% Cu)	As (3) but poorer wetting. Damage only slightly less severe.
(5) Cupric oxide-Goulac powder	3548	1-303 (0·2% Cu)	Easily mixed; suspension settles quickly; wetting poor. Damage as in (1).
(6) do.	do.	1-606 (0·1% Cu)	As (5).
(7) "Avon" Colloidal Copper	3673	1%	Easily mixed; excellent suspension; moderate wetting. Damage severe but less so than with copper oxides.
(8) do.	do.	0·5%	As (7).
(9) 25% Tetramethylthiuram disulphide dispersion	3663	1%	Easily mixed but excessive frothing; excellent suspension and wetting. No damage.
(10) 20% Ammonia-Shirlan preparation	3664	1%	Easily mixed; copious granular precipitate on diluting; excessive frothing; excellent wetting. No damage.
(11) Oil-Shirlan preparation (25% Shirlan, 20% white oil)	3665	1%	Easily mixed; good suspension; excellent wetting. Slight russeting of fruit.
(12) Copper-8-hydroxyquinoline (20% base)	3666	1%	Easily mixed; excellent suspension; good wetting. No damage.
(13) do.	do.	0·5%	As (12).
(14) 10% 1-Chloro-2-naphthol miscible oil	3667	2%	Fairly easily mixed, giving an opalescent emulsion; very good wetting. Fruit russeted; slight leaf-burn.
(15) do.	do.	1%	As (14).
(16) Agral AX-Agral SRT (miscible oil control for 3667)	3668	2%	Easily mixed; very good wetting. No damage.
(17) 10% Brilliant Green on Bentonite	3669	1%	Rather difficult to mix; excellent suspension, very little colour in solution; poor wetting. Very persistent deposit. No damage.

Product.	E.M.R.S. Ref. No.	Concentration (by weight).	Remarks.
APPLIED ON 9TH JUNE.			
(18) "Washed" cottonseed oil-Bordeaux mixture	3678	0·8% copper sulphate (0·2% Cu) 1·2% hydrated lime 1·0% "washed" c.s.o.	Good emulsion; fair wetting; good, even deposit of Bordeaux and persistent film of oil. No damage on Worcester or Bramley, slight spotting of fruit on Lane's. Considerable leaf-spot on Cox's but damage less severe than with 0·1% Cu elsewhere. No distinction between "washed" and "edible" except, perhaps, on Cox's where there was possibly very slightly less damage with "edible".
(19) "Edible" cottonseed oil-Bordeaux mixture	3679	0·8% copper sulphate (0·2% Cu) 1·2% hydrated lime 1·0% "edible" c.s.o.	
(20) "Lunevale" Burgundy	3659	1-100 (0·2% Cu)	Easily mixed; good suspension; excellent wetting. Very severe leaf-burn and fruit-russet.
(21) do.	do.	1-200 (0·1% Cu)	As (20) but damage less severe.
(22) "Colloidal copper" (copper hydroxide)	3697	1-30 (0·2% Cu)	Easily mixed to give a brown, colloidal suspension. Extremely severe damage (all leaves killed within three days).
(23) do.	do.	1-60 (0·1% Cu)	As (22) but damage slightly less severe.
APPLIED ON 16TH JUNE.			
(24) "Colloidal copper"	3697	1-120 (0·05% Cu)	As (22). Fruit russeted and cracked, considerable leaf-burn.
(25) do.	do.	1-240 (0·025% Cu)	As (24) but damage to fruit slightly less severe.

SUMMARY.

Tests of the phytocidal properties of fifteen chemical preparations, intended for use as fungicides, are described.

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(2) MONTGOMERY, H. B. S., MOORE, M. H. and SHAW, H. "Field trials in 1935 of the fungicidal and phytocidal properties of certain new chemical preparations." A progress report. E. Malling Res. Sta. Ann. Rep. for 1935 (1936), 198-203.

FIG. 1.

Fruitlets of Allington Pippin in July. *Top line :* sprayed with a colloidal copper preparation, "Bouisol", at 0·5 per cent. *Middle line :* sprayed with Bordeaux mixture, 3-9-100. *Bottom line :* sprayed with lime-sulphur, 1 per cent.

A FIELD SPRAYING TRIAL OF COMBINED FUNGICIDE-INSECTICIDE SPRAYS IN 1936

A PROGRESS REPORT

By M. H. MOORE and H. B. S. MONTGOMERY

Introduction.

In 1936, for the fourth successive year, combined fungicide-insecticide sprays were experimentally used on Cox's Orange Pippin. The previous three seasons' trials were :

In 1933 (7). With lime-sulphur, weaker than normal pre- and post-blossom as the fungicide, and sulphite lye as the spreader, nicotine was tested against derris as the insecticide. Nicotine was the more effective against Apple Sawfly, its action being probably that of an ovicide. Heavy spraying with the lime-sulphur and spreader gave good Scab-control, two pre-blossom sprays being no more effective than one, probably because of very dry weather in spring.

In 1934 (8). With lime-sulphur, at normal dilution pre- and post-blossom, as the fungicide, and nicotine and lead arsenate as the insecticides, comparison was made between three different spreaders as addenda. The fungicidal efficacy of lime-sulphur was influenced very little by varying the kind of spreader used. Two pre-blossom sprays were more effective than one, while nicotine, as an ovicide, gave very good control of Apple Sawfly.

In 1935 (9). With lime-sulphur, weaker than normal pre-blossom and at normal dilution post-blossom, as the fungicide, and nicotine, lead arsenate and petroleum-oil emulsion, as the insecticides, an attempt was made, by including a " no-spreader " treatment, to show whether the addition of a spreader enhanced the effectiveness of lime-sulphur or of nicotine. Severe frost in May almost ruined the crop, but the data that were obtained suggested that the inclusion of a spreader added nothing to fungicidal efficiency. Two pre-blossom lime-sulphur sprays were again more effective against Scab than one. Petroleum-oil emulsion, applied pre-blossom, caused severe leaf-burn and defoliation.

In 1936. The experiments included three distinct projects :

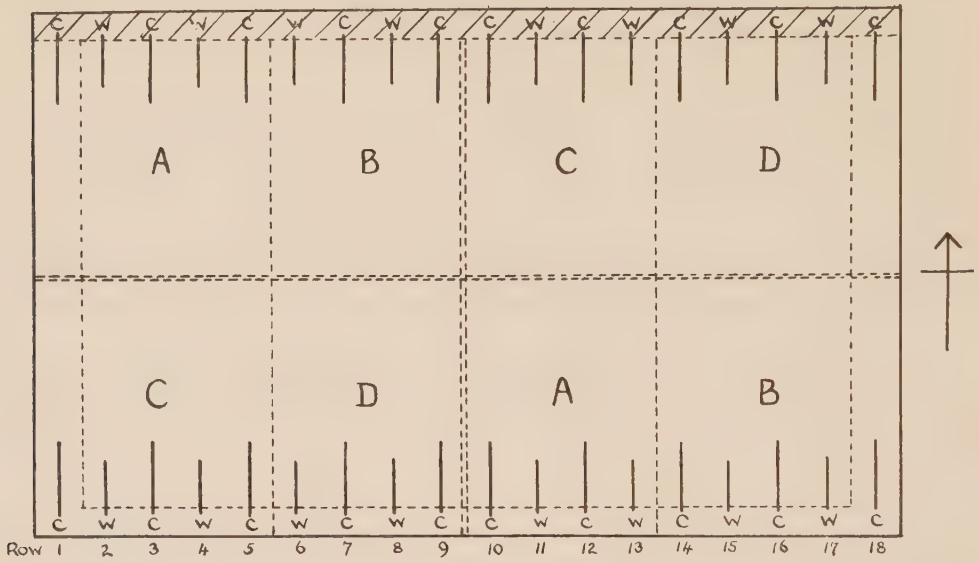
(i) To test the effect on fungicidal and insecticidal efficiency of the addition of a spreader to lime-sulphur with insecticides (lead arsenate and nicotine).

(ii) To test the fungicidal value of lime-sulphur diluted to 1% for all applications, pre- and post-blossom. Modern tendencies in spraying are towards high nozzle-output of spray under high pressure, and while the dilution of lime-sulphur used pre-blossom remains at " normal " (i.e. 2·5% or 3%), there is a danger of increased spray-injury as a result of the change in the mode of spraying.

(iii) To test the fungicidal value of very weak Bordeaux mixture. The 8-12-100 mixture evidently is too strong for most, if not all, apple trees, yet it is indisputable that Bordeaux mixture is an excellent protective fungicide. Preliminary experiments have already been made with 4-18-100 (6) and with 5-15-100 (2) mixtures. A 2-10-100 mixture was used for Cox's in the present trial, and petroleum-oil emulsion was included post-blossom as an acaricide.

Description of Experiments.

This particular plot of Cox's Orange Pippin has already been fully described elsewhere (8, 9). As in 1935, it was divided into eight sub-plots, and the four different spray-treatments were distributed in duplicate so that each was applied to trees worked respectively on eight different rootstocks. Positional variation also was allowed for as much as possible in the arrangement of treatments, which is shown diagrammatically below :



The headland trees on the East, South and West sides of the plot were regarded as " buffers ", and they were not included in the four main treatments. They were sprayed, however, with the same sprays as the trees in the adjacent sub-plot, except that they had no green-bud application. A line of trees (at right angles to the rows) at the North end of the plot remained unsprayed as controls, seen shaded in the plan. Each of these trees is worked on a different rootstock.

A row of Worcester Pearmain occurs between each two Cox's rows. A few years ago these trees were Stirling Castle, but they were " over-worked " to Worcester and are now cropping. They were included in the spraying trial this year.

The treatments were :

Period.	Treatment.			
	a	b	c	d
Green-bud	LS.A.	LS.'A.	LS.'A.Leth.	BM.A.
Pink-bud	LS.A.	LS.'A.	LS.'A.Leth.	BM.A.
Petal-fall	LS.N.	LS.N.	LS.N.Leth.	BM.N.Oil
Three weeks after petal-fall	LS.	LS.	LS.Leth.	BM.

The assumption was made from the results of former experiments that two pre-blossom sprays would, in most seasons, be preferable to only one, especially on well-established trees now sixteen years old. Hence the comparison was relegated to the " buffer " trees, from which the green-bud spray was omitted for that purpose.

LS. *Lime-sulphur solution* of specific gravity 1·3, and containing approximately 20% (by weight) sulphur as polysulphides: **2·5% pre-blossom, 1·0% post-blossom.**

LS'. *Lime-sulphur solution*, as above: specially dilute for **pre-blossom** use, i.e. **1·0%**, and the same **post-blossom.**

A. *Lead arsenate paste* containing 15-16% (by weight) arsenic pentoxide: **0·4%, pre-blossom.**

N. *Nicotine* of purity 95-98%: **0·05%, at petal-fall** (for Sawfly).

Leth. *" Lethalate " Standard Wetting Preparation* containing 75% commercial sodium lauryl sulphate, 20% alkali salts of di-isopropyl naphthalene sulphonic acids, and 5% natural gum: **0·05%, at all four periods.**

BM. *Home-made Bordeaux mixture*: **0·2% copper sulphate, 1·0% hydrated lime, i.e. 2-10-100 at all four periods.**

Oil. *Refined petroleum oil*: **1%, at petal-fall.** For details of the specification of the oil see (1), page 120. The oil was emulsified with the precipitate of the Bordeaux mixture.

Application of Sprays.

A 2½ h.p. portable outfit supplied two 4 ft. lances, each with double nozzles and $\frac{3}{64}$ in. discs, at a pump pressure of 200-50 lb. per sq. in. Pre-blossom, this outfit was stationary, and the lances were fed through overground steel mains; post-blossom, the outfit was towed behind a tractor and steel mains were not needed—a method which proved very satisfactory.

Green-bud spray. Applied on 23rd April, after a prolonged period of cold weather with strong, north winds, during which the trees had made very little progress from an early burst into leaf. The weather (and the tree-condition) had been favourable for Scab but unsuitable for spraying, and a spray even earlier than green-bud might have proved beneficial in 1936.

It was a fairly warm day with a freshening S.W. breeze. On average, about 1½ gallons of spray were used on each tree.

Pink-bud spray. Applied on 5th May under excellent conditions—sunny and warm with little wind. Again, about 1½ gallons per tree were used. Much Scab was seen on the young leaves of trees which had had no green-bud spray; a sprinkling was also apparent on sprayed trees, particularly those with Bordeaux and with 1% lime-sulphur. There was slight marginal leaf-burn on trees sprayed with 2·5% lime-sulphur, but very little Scab.

Petal-fall spray. Applied on 25th May in warm, dull weather: most of the petals had fallen. In making the Bordeaux-oil emulsion, the oil and the dissolved copper sulphate were stirred together and added to the lime, already diluted in the bulk of water, in the spray-tank. The agitator kept the mass well mixed while the copper sulphate and oil were being added.

Nearly 2 gallons per tree were used this time. Scab was, by now, very severe on the controls ; it was conspicuous on trees sprayed with Bordeaux and with 1% lime-sulphur, but it was not easy to find on those sprayed with the 2·5% solution. Nicotine was included in all sprays at this period for Sawfly-control.

Second post-blossom spray. Applied on 16th June in warm, fairly sunny weather with a fresh S.W. breeze. The amount of spray used per tree was similar to that used at petal-fall. It was intended to include oil again with the Bordeaux mixture, but the trees sprayed with this mixture at petal-fall now showed signs of such severe injury (leaf-burn, defoliation, and fruit-russeting) that it was considered wise to omit the oil. At the time it seemed absurd to impute to such a weak Bordeaux mixture the sole responsibility for this spray-injury, yet afterwards it was concluded that this must, indeed, be so, for weak Bordeaux mixture, without oil, caused similar injury on other experimental trees at the Research Station (see this Annual Report p. 261). Some leaf-drop had occurred on all trees, controls included ; evidently this was, however, a drought effect, for the weather during May was very dry.

Lead arsenate paste was included in some of these second post-blossom sprays to test its effect in controlling Codling Moth. Further details of this trial will be found in the appendix to this paper.

Biological Observations and Weather Conditions.

Scab. In accordance with custom, scabbed leaves of 1935 were kept all winter under natural conditions in the open, and were examined periodically in spring. On 3rd April, the contents of the asci were undifferentiated, but by 14th April, some ripe ascospores were present in leaves of Cox's Orange Pippin. More and more were found as May approached, and by 1st May, ripe ascospores were very numerous.

The following points have been extracted from the weather records* :

April	..	Cold, dull and rather dry. Rainfall 1·31 in., 0·75 in. of this on the 20th and 21st.
May	..	Abnormally dry and fairly mild. Northerly winds prevalent. Rainfall 0·44 in., 0·40 in. of this on the 16th and 30th.
June	..	Cool and very wet, especially the second half of the month when heavy thunderstorms frequently occurred. Rainfall 3·95 in.; heavy on the 1st (0·35 in.), 21st (0·49 in.), 28th (1·11 in.) and 29th (0·37 in.).
July	..	Dull, rather close and wet. Rainfall 2·80 in., fairly uniformly distributed throughout the month.
August	..	Wet at first, then very dry and sunny. Rainfall 1·20 in., all before the 20th, 0·86 in. of this on the 9th and 10th.

As in 1935, Scab-infection occurred early, probably around mid-April and, as stated above, a first spraying in the third week of April was probably too late for protection against primary infection. In 1935, a dry summer checked the development of Scab already flourishing in early May (9) and, for a time, conditions were similar in 1936. When the wet weather arrived in June, however, Scab, in common with several other " wet-weather " diseases, obtained a thorough hold, particularly where control in the early stages had not been perfect.

* The writers are indebted to Mr. H. C. Chapelow for these data.

TABULATED DATA.

Rootstocks.	(a) **Lime-sulphur** (2·5% pre-blossom, 1% post-blossom)			(b) **Weak Lime-sulphur** (1% pre- and post-blossom)			(c) **Weak Lime-sulphur** (1% pre- and post-blossom) **with spreader.**			(d) **Weak Bordeaux mix** (2- 10- 100 pre- a post-blossom)		
	No. of Trees.	Average No. of Fruits picked per tree.	Average Scab-equiva-lent.	No. of Trees.	Average No. of Fruits picked per tree.	Average Scab-equiva-lent.	No. of Trees.	Average No. of Fruits picked per tree.	Average Scab-equiva-lent.	No. of Trees.	Average No. of Fruits picked per tree.	Av Sc equ le
						VARIETY—COX'S ORANGE PIPPIN.						
I.	3	179	3·3*	3	330	7·7	4	348	4·0*	4	371	
				(1)	(390)	(17·7)						
II.	4	394	15·2*	3	475	19·4	3	650	13·7*	3	839	1
							(1)	(509)	(22·7)*			
III.	4	357	7·3	4	234	5·5*	3	406	9·0	3	491	
										(1)	(302)	(
IV.												
							(4)	(742)	(12·9)*	(3)	(1070)	(
V.	4	288	13·7*	4	418	17·0	3	441	13·6*	3	665	
							(1)	(483)	(28·3)*			
VI.												
	(7)	(378)	(12·2)*	(7)	(594)	(15·3)						
IX.	4	253	2·5	4	327	3·0*	3	368	6·7	3	338	
										(1)	(554)	(1
X.	2	348	16·1*	3	415	19·0	4	352	12·3*	4	804	1
				(1)	(216)	(50·1)						
XIII.	3	147	9·3	3	136	8·2*	4	348	11·7	4	538	1
	(1)	(105)	(8·5)									
XV.												
							(4)	(243)	(18·9)*	(4)	(607)	(
XVI.	3	203	8·3	3	154	9·2*	4	264	14·2	4	330	
	(1)	(601)	(16·6)									
Average for treatment		**271**	**9·5**		**311**	**11·1**		**397**	**10·7**		**547**	
		(361)	(12·4)		(400)	(27·7)		(494)	(20·7)		(633)	(
						VARIETY—WORCESTER PEARMAIN.						
Average for treatment	28	25	3·4	28	19	4·6	26	31	9·0	28	62	
	(2)	(27)	(11·3)	(2)	(24)	(24·2)	(2)	(19)	(7·1)	(2)	(147)	(2

Sawfly and Codling Moth. Biological notes on these two pests are given in the appendix.

Spray-injury. Lime-sulphur, applied pre-blossom at 2·5%, caused some marginal leaf-burn, which was not serious. By 23rd June, leaf- and fruit-drop was noted on all lime-sulphur-sprayed trees. This was conspicuous but not severe really, and undoubtedly it was coupled with the drought and with hot, sunny conditions in May. It probably had a bearing on the results of Scab-estimations on the fruit, as will later be indicated.

The outstanding point about spray-injury in 1936, however, was the damage caused by very weak Bordeaux mixtures, as well as by stronger ones. The cause is undetermined, though, in view of the prevalence, during abnormally long periods in spring, of cold, drying winds, accompanied later by excessive rain, it is reasonable to suspect that these unusual weather conditions rendered the trees specially susceptible to copper-injury.

In the instance under comment, the injury was as severe as has often been noted (3) on Cox's sprayed with a " full-strength " (8-12-100) mixture. The leaves were badly burnt, many had dropped, and the fruits were very severely russeted, and, in many cases, split to the core. The injury was not as severe on Worcester as on Cox's.

Methods Used to Assess Results.

The fruits picked from each tree, Cox's (random samples) and Worcester (whole crop), were Scab-graded by the " category " method (3, 5). The figures obtained for each Cox's tree were averaged to give the results here classified, but with Worcester, cropping was so irregular (the " overworking " was not all done during one season) that the results were assessed, not for individual trees, but in mass according to spray-treatment. The data obtained on Worcester must therefore be regarded as merely supplementing those obtained on Cox's.

The recording of Sawfly and Codling was undertaken by Mr. W. Steer, who has dealt with these aspects, and with the results obtained, in the appendix.

Results.

In the tabulated data, an asterisk denotes that the result was obtained from the West half of the plot, where, as previous experience has shown, the incidence of Scab normally is not as severe as on the East half. Where only one pre-blossom spray, at pink-bud, was given, the figures are shown in brackets. For convenience, only the fungicides are listed at the tops of the columns. The complete spray-programmes are given on pages 268-9.

The Crop. It is clear from the figures that lime-sulphur, used with or without a spreader, caused fruit-drop, though the injury was the less pronounced where the spreader was used. This fruit-drop was more beneficial than otherwise, because nearly all the trees were carrying a very heavy crop. Bordeaux mixture did not cause fruit-drop, but, as previously stated, the fruits were severely russeted and the leaves burnt.

Where the green-bud spray was omitted (figures in brackets), more fruits per tree were picked than where the green-bud spray was applied. A satisfactory explanation for this has not been found; the unit of trees sprayed only once pre-blossom is small and the figures are variable -moreover, positional variation probably plays a large part, for all the trees concerned are on headlands. The result, though curiously consistent, may therefore be only coincidence. In 1934 (8), a similar result was obtained on a much larger scale, but in that instance, the green-bud spray had caused severe injury to the rosette leaves and the flower trusses.

Scab (*Venturia inaequalis* Cooke (Wint.)). Two pre-blossom sprays were yet again more beneficial than one, except with the Bordeaux mixture. It would be expected that, with Bordeaux, as well as with lime-sulphur, the earlier spray would prove beneficial in a spring such as that of 1936. That it did not is undoubtedly due to the loss of the first-infected leaves, through spray-injury, before spores from them could severely infect the fruits. Thus the figures for Bordeaux-sprayed fruits are misleading when considered apart from other effects of the spray. On Worcester, where leaf-burn was less severe, the difference between the one and two pre-blossom applications was apparent on the fruits.

Scab-control was not as good as usual, probably because the green-bud spray might, with advantage, have been applied a little earlier, or, alternatively, an extra application, even earlier than green-bud, might have been added to the programme of sprays. Where lime-sulphur was used at 2·5% pre-blossom, the difference between the figures for one pre- and for two pre-blossom applications is less than that where 1% was used pre-blossom. This suggests that the effect of the stronger spray, coupled perhaps with that of desiccating northerly winds, " burnt " already existing Scab-spots on the rosette leaves, thus tending to obviate subsequent fruit-infection.

The use of 1% lime-sulphur, pre- and post-blossom, proved very promising, for no significant increase in Scab-control on the fruits was achieved where the strength of the pre-blossom applications was increased to 2·5% (the " normal "). On the basis of the one year's figures, however, it would be premature to recommend the general use of the weaker pre-blossom spray, especially as drought conditions in May, 1936, undoubtedly helped to eliminate differences that were observed early in the season. There was, at one early period, much more leaf-infection on trees sprayed with 1% pre-blossom than on those with 2·5% pre-blossom: this difference practically disappeared when drought-effects passed and many of the scabbed leaves had dropped. On certain other varieties in another trial on the Research Station, some evidence was obtained that the stronger pre-blossom lime-sulphur spray was more effective than the weaker (see this Annual Report, p. 262).

The present experiments indicate, however, that the disparity between the pre- and post-blossom strengths of lime-sulphur now in general use may successfully be reduced on the basis of further experiment. It is not suggested that the use of lime-sulphur as dilute as 1% pre-blossom may ultimately be necessary or even desirable, but a reduction in strength for pre-blossom use would be welcome if only as a means of obviating some of the risk at present entailed in heavily spraying varieties* that tend to be sulphur-sensitive with a spray which, especially under certain weather conditions, is undoubtedly on the borderline of safety.

No evidence was obtained that the addition of the spreader to lime-sulphur caused improvement in Scab-control.

Scab-infection on the control trees was extremely severe. By August, most of the trees were nearly defoliated and the fruits were small, distorted and unsaleable. The most severely-affected trees were those on stocks No. I, VI and X, while those on Nos. IV and XIII were lightly affected in comparison. As only one tree on each stock is compared, however, this classification cannot be relied upon; nevertheless, it is supported in general by the classification based on fairly severe infection on control trees in 1930 (4).

Red Spider (*Oligonychus ulmi* C. L. Koch). Detailed records of the prevalence of this pest were not made because the trial of refined petroleum oil with the Bordeaux

* Such as Newton Wonder, Beauty of Bath, Lane's Prince Albert, Duchess' Favourite, Cox's Orange Pippin, Rival, Lord Derby, etc.

mixture was not completed, for reasons already given. General observations failed to reveal any effect of the spreader on the acaricidal efficiency of lime-sulphur, which was moderately good, though on the control trees and on those sprayed with Bordeaux, infestation was severe, eggs being readily found even in and around the " eyes " of the mature fruits. Evidently, any beneficial effect produced by the one application of oil at petal-fall was dispelled as the season progressed. Further tests of the oil-Bordeaux mixture as a combined acaricide-fungicide will be made on a smaller scale until its phytocide potentialities are better known.

APPENDIX

By W. STEER

In the foregoing trial observations were made on Sawfly on Cox's Orange Pippin in connection with the petal-fall application of nicotine, and on Codling Moth in connection with the lead arsenate applied in the three-weeks spray.

SAWFLY.

It will be seen from the plan and from the list of spray treatments on page 269 that nicotine was applied at petal-fall in combination with

1. Lime-sulphur (4 plots).
2. Lime-sulphur + " Lethalate " (2 plots).
3. Bordeaux-oil emulsion (2 plots).

When the sprays were applied (25th May) no sign of hatching could be found on the Cox's, although the first larva had been seen on neighbouring Worcesters on the previous day. In this trial, therefore, spraying took place just before the beginning of hatching, which, as Hey and Steer have shown (10), is the latest date when a " petal-fall " nicotine spray can be relied on to give satisfactory results against Sawfly.

Since very few Sawfly-damaged apples remain on the tree till picking-time, the picked crop was ignored and the records of Sawfly damage were confined to the " drops ", i.e. all the fruitlets that fell, from the very first and smallest (falling soon after petal-fall) to the half-grown apples of the normal June-July drop.

As the infestation was insufficient to cause excessive fruit-drop by comparison with the normal " June drop ", the records may be regarded as adequate for comparative purposes.

All the " drops " were examined from two trees in each of the eight sub-plots and from all ten control trees.

The results were as follows:

Treatment.	Fruits examined.	No. sawfly-damaged.	% sawfly-damaged.
A. LS. + Nicotine	3,727	57	1·5
B. LS. + Nicotine	5,876	42	0·7
C. LS. + Nicotine + " Lethalate "	3,974	41	1·7
D. B.M.-Oil emulsion + Nicotine ..	3,014	72	2·4
Controls (unsprayed)	12,151	1,351	11·1

Each of the spray-treatments gave good results. The addition of a spreader ("Lethalate" at 0·05%) failed to improve the performance of the lime-sulphur and nicotine spray—a result which confirms the findings of Steer and Thomas (11). On the trees sprayed with the Bordeaux-oil emulsion and nicotine spray, Sawfly damage was slightly, but not significantly, greater than on the other sprayed trees.

Codling Moth.

One of each pair of sub-plots received lead arsenate (paste, 0·4%) in the second post-blossom spray on 16th June. The object was two-fold. It was desired to ascertain: 1. whether adequate control of Codling could be obtained with lead arsenate in the normal second post-blossom Scab spray, so obviating the need for the late-June application which Steer (12) has suggested, and 2. whether the addition of a spreader is likely to affect the efficiency of such a spray against Codling.

Most of the Codling eggs on these trees were laid in the last week of June and the first half of July.

Counts were made of random samples of fruit from every tree in one row in each sub-plot, with the following results:

	% fruits attacked by Codling Moth larvae.	
	Arsenate omitted.	Arsenate included.
LS. 1%	2·1	0·8
LS. 1%	1·5 (average 1·2)	0·8
LS. 1% + "Lethalate"	0·5	0·8
Bordeaux 2-10-100	0·6	0·3

These figures are inconclusive as the infestation was low and unevenly distributed. Elsewhere in this Annual Report (13) the results are discussed in relation to other observations on Codling Moth.

Summary.

Good control of Apple Scab was given by four applications of lime-sulphur on Cox's Orange Pippin and Worcester Pearmain. The sprays were applied at green-bud, pink-bud, petal-fall and three weeks after petal-fall. The seasonal conditions of 1936 were very favourable for Scab-infection, which became extremely severe on unsprayed control trees, especially, with Cox's, those on certain rootstocks.

No evidence was obtained that the inclusion of a spreader with lime-sulphur affected Scab-control. Lime-sulphur at 1% pre- and post-blossom was as fungicidally effective (when judged by grading Scab-spots on the mature fruits) as at 2·5% pre-blossom followed by 1% post-blossom. From general observation on the foliage, however, the spray at 1% throughout seemed to be the less effective. At 1% post-blossom, lime-sulphur caused fruit-drop, though this did not seriously affect the ultimate crop, and was, perhaps, even beneficial.

Weak Bordeaux mixture (2-10-100) caused severe leaf-burn, defoliation, and fruit-russet; it gave efficient Scab-control on the fruits, though probably by indirect and undesirable means. The effect of the inclusion of refined petroleum oil as an acaricide was not followed up for reasons given.

The addition of nicotine to the petal-fall spray controlled Sawfly satisfactorily, whether a spreader was added or not. Inconclusive results were obtained by adding lead arsenate, to control Codling Moth, to the second post-blossom spray.

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NOTES ON THE CONTROL OF STRAWBERRY MILDEW *(SPHAEROTHECA HUMULI)*

By M. H. MOORE

During the 1935 summer, Strawberry Mildew was seen to be rapidly developing on extensive series of plants that were being used for various important experimental purposes. This circumstance gave an opportunity for testing the respective merits of sulphur dust and of a sulphur-containing spray for controlling the disease.

Experiments in 1935.

A small trial was planned on a plot of about 600 Royal Sovereign strawberries, planted in October, 1934, that had hitherto been used for observations on Strawberry Root Rot. The planting had been statistically arranged, and each sub-plot of twenty-four plants was provided with " guard rows " which acted as " buffers " to the sprayed and dusted plots.

The following treatments were heavily applied on 15th and 16th August, 1935 :

(*a*) Lime-sulphur, of specific gravity 1·30 and containing approximately 20% polysulphide sulphur by weight, **at 1%** by volume (i.e. 1 gal. concentrate to 99 gal. water).
(*b*) Lime-sulphur, **at 2%**.
(*c*) Lime-sulphur, **at 3%**, on " buffer " plants only.

each with " Lethalate "* Standard Wetting Preparation, at 0·05%, as **spreader.**

(*d*) Flowers of Sulphur.
(*e*) Water. This " control-treatment " served to distinguish the merely mechanical and physiological effects of the sprayings from the effects of the fungicide incorporated in (*a*), (*b*) and (*c*).

The sprays were applied from a barrel-type, hand-operated machine developing pressure up to 300 lb. per sq. in. (a lance with a single nozzle was used) ; the dust from a hand-operated dust-blower. Drift was arrested by the use of a small screen.

It must be emphasized here that the disease was already well established, for the season was well advanced. The most that could be expected from this trial was an indication of the merits of the various treatments mainly as *direct-action fungicides*, i.e. of their action on the already-established fungus. Where possible, it is more satisfactory to use fungicides as *protectants*, i.e. in anticipation of fungus-attack and to keep healthy plants free from disease.

On 19th and 20th August, leaflets were picked at random from plants under each treatment, and they were microscopically examined in the laboratory. It was then seen that :

(i) There was complete collapse of all mildew, and no recovery, with each of the three lime-sulphur treatments.

(ii) There was little collapse on dusted leaves. Bunches of mildew-spores, however, were completely covered with sulphur particles, and individual spores were shrunken and of very unhealthy appearance.

* Containing 75% commercial sodium lauryl sulphate, 20% alkali salts of di-isopropyl naphthalene sulphonic acids and 5% natural gum.

(iii) The fungus was in its normal vigorous state on water-sprayed " controls ". A few isolated instances of collapsed mildew-patches were found, but these were on old leaves which normally are unable to support vigorous mildew growth.

A further similar examination of freshly-gathered leaflets was made on 28th August. The result differed in only one respect from the earlier one : there was now patchy but vigorous recovery of mildew on the dusted leaves, though, in the main, the infection was still subdued.

This second, detailed examination had been preceded, on 27th August, by a general inspection of the growing plants. It was found that, especially by concentrating attention on the young—though not the youngest—leaves (i.e. those towards the centres of the plants), the " control " sub-plots could be distinguished without difficulty. The younger leaves on " control " plants were curled upwards from the margins, and were distinctly white in appearance. Those of the treated plants were, in general, flat, green and healthy-looking.

Some marginal leaf-burn accrued on plants sprayed with the 3% and the 2% solutions, but the 1% solution seemed quite safe. The injury had no serious effect, for new leaves continued to be formed and, after a few weeks, the burning was not noticeable.

On 8th November the " spread " of each plant was measured. The records were classified according to fungicide treatment, and they yielded this summary :

	Average " spread " per plant.
Lime-sulphur (1%)	14·8 inches.
Lime-sulphur (2%)	15·2 ,,
Flowers of sulphur	14·4 ,,
Controls	14·3 ,,

The " buffer " plants, which received the 3% solution, were not measured. It is clear that spraying did not adversely affect growth.

Conclusions.

Spraying with lime-sulphur and dusting with flowers of sulphur each gave satisfactory control of Strawberry Mildew by direct action. The effect of the spraying was more prolonged than that of the dusting, which suggests that dust might need more frequent application than spray to produce the same beneficial effect. The plants were not seriously injured by any of the treatments.

Experiments in 1936.

Evidently it was desirable to test the merits of these treatments as *protective* fungicides, so in spring, 1936, another trial was planned on the same plants. Four treatments were chosen :

(*a*) Lime-sulphur **at 2%**.
(*b*) Lime-sulphur **at 2%** + " Lethalate " Standard Wetting Preparation, at 0·05%, as **spreader.**
(*c*) Flowers of Sulphur.
(*d*) Untreated " controls ".

These were applied twice before blossom, viz. on 15th April and 4th May, while the " buffer " plants were sprayed on only the second occasion with lime-sulphur at 2%.

The treatments were so arranged that any cumulative effect of spraying, of dusting, or of withholding treatment, in 1935, was distributed evenly throughout the 1936 series.

The " cover " obtained with lime-sulphur alone was rather patchy, but it was very good where the spreader was used. It seemed easier to wet the older leaves than the younger ones.

There was more marginal leaf-burn from the spraying than in 1935, probably because the leaves were younger and more tender, but this was not serious and the plants soon grew away from it. The presence of the spreader made no detectable difference here. The dust caused no damage.

Mildew did not appear until just before flowering (it became very severe later—unexpectedly, considering the relative lack of hot, dry summer weather), and it was, therefore, not possible to assess the value of two sprayings compared with only one. Post-blossom treatments were not given owing to the pressure of other work, but after mildew-infection had begun, the control plants could be distinguished from the treated plants, as in 1935, for several weeks. Again, spraying had a more lasting effect than dusting, although no evidence was obtained that the presence of the spreader was favourable or otherwise to protection against mildew-attack.

The fruits from all sub-plots were weighed and graded into mildewed and non-mildewed berries. The total number of mildewed berries was small—only twenty-four in 230 lb. fruit—but all except one of these were picked from control plants.

Conclusions.

Exactly as in 1935, though, in the present instance they concern protective, and not direct, fungicidal action.

Discussion of Results, and Recommendations.

From the practical point of view, dusting is a more attractive method of control than spraying because it can more rapidly be done. It must be practised more frequently than spraying, however, for its effect is not so prolonged ; a deposit of dust is likely to be more rapidly washed off by rain than a deposit of spray. It is much more desirable to start spraying or dusting before the disease appears than afterwards for there is greater likelihood of getting good control, particularly if dusting is favoured. The grower must decide whether to spray or to dust in view of his own circumstances—he must be prepared to dust once during every week or ten days, and to spray once every two to three weeks when infection is likely to occur. Lime-sulphur would have more lasting qualities at 2% than it would at 1% because more sulphur would be deposited from the stronger spray. There is a danger, however, that the 2% solution might cause fairly severe marginal leaf-burn in hot weather, and this burning would probably be as deleterious for a time as would the disease.

For fruiting plants, spraying or dusting should begin during the latter half of April when the young leaves are rapidly unfolding. One or two dust-applications might be made after the main flowering-period, but these should not be delayed if the berries are to be canned, since a deposit of sulphur on the berries is unfavourably received by the canners. Post-cropping applications are, again, a matter for the grower to decide. Severe mildew undoubtedly weakens the plants ; the leaves are desiccated and the functioning leaf surface is greatly reduced, thus affecting the next year's crop. A light attack is probably not very harmful, but it acts as a source of infection for any young plantations near and, should the conditions be favourable, it might become epidemic in a short time.

For runner beds and maiden plantations, which normally are not severely infected until the summer, and where fruits are not a consideration, treatment might well begin when attention can be spared after picking and marketing the crop from fruiting plants. Earlier treatment can, of course, safely be given when weather conditions are such as to promote any possibility of severe early infection. Dusting or spraying should be continued periodically throughout the summer, particularly when weather conditions are favourable for infection, i.e. in periods of hot, dry weather after recent growth has been rapid and lush.

It should not be forgotten that control of Strawberry Mildew is an important consideration where late summer roguing for virus-infected plants in runner beds (particularly those in their second year) is contemplated. The presence of mildew is a great handicap to easy and rapid roguing, for the leaf-symptoms of mildew tend to hamper the ready recognition of " yellow-edge " symptoms. Preventive treatment for mildew is essential in this instance, for dustings done when the disease is already well established would be too late.

Acknowledgment.

The writer is indebted to Miss M. E. Renwick, Miss R. F. Stern, and Mr. H. B. S. Montgomery, all of whom gave valuable assistance in the field.

Summary.

The results are described of two seasons' field experiments on the control of Strawberry Mildew by the use of lime-sulphur and of sulphur dust. Each of these controlled the disease, though dust requires more frequent application than spray. The use of either of these as protectants is urged, treatment for fruiting plants to *begin* during the latter half of April and, for runner beds and maiden plantations, where fruits are not a consideration, normally during the first half of July.

Section IV

BULLETINS FOR FRUITGROWERS

POMOLOGY

A PRACTICAL EVALUATION OF ROOTSTOCKS IN COMMERCIAL CIRCULATION

By N. B. BAGENAL, R. J. GARNER and R. G. HATTON

During the last few years five reports* have been published by this Station on the subject of rootstocks for apples, pears and plums. These reports set out in detail the data obtained during the last twenty years from experimental sets of trees of several varieties grown at East Malling. This information has been supplemented by numerous subsidiary trials planted under varying growth conditions in many different centres in the South-East of England. At a meeting of nurserymen fruit tree raisers held at East Malling in the summer of 1936, these experimental findings were summarized in their application to present-day commercial practice, and fully discussed. In the light of that discussion the following recommendations have been drawn up to serve as a general guide to the rootstocks at present available, and likely to be retained as of commercial value until replaced by something better.

Vegetatively raised rootstocks are recommended because they produce trees which can be relied upon to behave in certain definite ways in regard to compatibility, growth and cropping.

One point of immediate practical importance to the fruitgrower which needs stressing is in connection with scion-rooting, a condition more commonly occurring with apples and pears on dwarfing stocks than is generally supposed, and which entirely defeats the objects for which such stocks are used. Tree-raisers can safeguard the grower against this problem by working their trees in such a way as to ensure that when planted out in their permanent positions there will be a sufficient length of stock stem between the union and soil level to minimize the risk of scion-rooting.

Fruitgrowers in their turn when ordering apple trees on dwarfing stocks and pears on quince, would do well to ascertain that the trees have not been worked too low down on the stock stem.

* E.44. "Peach Stock Trials." E. Malling Res. Sta. Ann. Rep. for 1928-30 (April, 1931). (II—Supplement.) 22-31.

E.66. "'Free' or Seedling Rootstocks in use for Pears: Their Description, Selection, Vegetative Propagation and Preliminary Testing." Journ. of Pom. and Hort. Sci., Vol. XI, No. 4. December, 1933. 305-34.

E.77. "Rootstocks for Pears." E. Malling Res. Sta. Ann. Rep. for 1934 (May, 1935). 75-86.

E.91. "Apple Rootstock Studies. Effect of Layered Stocks upon the Vigour and Cropping of Certain Scions." Journ. of Pom. and Hort. Sci., Vol. XIII, No. 4. December, 1935. 293-350.

E.110. "Plum Rootstock Studies: Their Effect on the Vigour and Cropping of the Scion Variety." Journ. of Pom. and Hort. Sci., Vol. XIV, No. 2. July, 1936. 97-136.

ROOTSTOCKS FOR APPLES.

Malling Number IX.—Jaune de Metz.

This may be said to be the only rootstock for apples in commercial use which invariably produces a relatively small quick-cropping tree, but it cannot be recommended for trees which are to be grown under adverse conditions. Trees on No. IX need good soil and good farming from start to finish. Particular attention should be given to firm staking, since the root system is naturally brittle, and the trees for this reason are predisposed to blow over in a bad gale if the stake fails to hold them up. This, however, is a weakness which can be guarded against in advance by efficient staking. Bush trees on No. IX are likely to require permanent stakes, and their branches need support as soon as they have to carry any weight of crop.

It has been said that No. IX is only suitable for dessert apples, but under our conditions Lane's Prince Albert and Bramley's Seedling have both done well on this stock.

Malling Numbers I and II.—Rivers' Broadleaf and Doucin.

The differences in stock-effect produced by these two stocks in early years were sufficiently marked to allow them to be grouped separately. No. II, owing to its earlier cropping and smaller amount of wood growth, was classed as semi-dwarfing, and No. I as vigorous. Since those early days, as might have been expected, scion varieties have reacted in different ways when worked on these two rootstocks. Bramley's Seedling and Cox's Orange Pippin on No. II in our experimental plantations are now considerably larger than on No. I, although with Lane's Prince Albert the reverse is the case. Trees of Worcester Pearmain on No. I are still ahead of those on No. II in the matter of size, and have produced rather better-coloured fruit.

It would seem that for the majority of bush trees these two rootstocks should be retained for the present, the choice between them depending on the scion variety required and possibly on the soil and climatic conditions of the area in which the trees are to be planted.

A stock widely produced on the Continent, but of universally poor performance in this country, is the Doucin Amelioré, or Malling No. V. Trees on this stock are particularly prone to show leaf-scorch under unfavourable growth conditions, and they have yielded very light crops. Fruitgrowers would do well to avoid buying trees on this rootstock.

Very Vigorous Rootstocks.

It is to be hoped that the very vigorous class of layered apple stocks has now been sufficiently proven to take the place of the mixed seedling "Crab" population. Layered stocks Malling No. XVI, Crab C, and Long Ashton OF5, recently renamed G8, have produced large trees which at East Malling would be suitably spaced at from 30 to 40 ft. apart according to scion variety. No. XVI is the more readily propagated, and is probably at present the most useful representative of the very vigorous group of stocks. It is produced on a large scale in Germany under the name of Ketziner Ideal.

On certain poor sandy soils Malling No. XII has given medium-sized trees which have cropped fairly early in life, but on average soils growth is super-vigorous and cropping is much delayed in trees on this stock. Malling No. XIII is easily raised, but at East Malling the trees have not maintained their early promise of vigour. It is, however, regarded as preferable to mixed seedling stocks owing to its greater uniformity. The stock is surface-rooting, and this probably accounts for the good behaviour of trees on No. XIII grown in heavy clay soils.

Other Layered Apple Rootstocks.

Other apple stocks which have been outstanding at East Malling are Malling No. IV and Malling No. VII. Trees on No. IV grow as vigorously as on No. XVI in the early years, have cropped exceptionally heavily, and have settled down into nice-sized bush trees. The stock has the disadvantage of being poorly anchored, almost all trees which have cropped on No. IV are now leaning over on all the soils on which we have tried them. In addition, it has not proved a good nursery stock under our experimental tests. Trees on No. VII grew as vigorously as on No. I in early years, but soon settled down and cropped heavily, and this stock has since behaved as a typical semi-dwarfing rootstock filling the gap between Nos. IX and the more vigorous stocks. Unfortunately, No. VII has proved to be extremely susceptible to root gall in the nursery, and though at East Malling this has not proved harmful to the trees, it certainly detracts from its value to the tree raiser. This susceptibility has been proved under conditions of artificial inoculation as well as under the Research Station soil conditions. In addition, Worcester Pearmain has cankered more on No. VII than on other stocks. Certain varieties, especially Worcester, on Malling No. XI, have behaved well in regard to cropping, but as this stock is exceptionally susceptible both to woolly aphis and to crown gall, it has not been recommended for general use.

Rootstocks for Pears.

Malling Quince A and Malling Quince B have behaved somewhat similarly in producing good bush trees, and they have maintained their vigour whilst cropping. In some cases Quince B has produced slightly larger trees with correspondingly heavier crops.

Malling Quince C has invariably produced a tree which has grown as vigorously as Quince A until it has cropped, when it has fallen behind Quince A in tree-size. Trees on Quince C have cropped heavily and early in their lives, even in the case of varieties such as Comice, Hardy and Pitmaston. It should be very useful for shy-cropping varieties and for small garden trees, and is an admirable stock for cordons. It suffers in the nursery from a leaf spot fungus which causes early defoliation if not controlled by Bordeaux spraying. Under certain seasonal conditions some varieties on Quince C have shown " rough bark " symptoms.

Layered pear stocks have not proved easy to produce economically in large quantities. This is a pity as seedling pear stocks are very variable, both in their compatibility and in their effect upon different scion varieties. Various methods of vegetative propagation are still being explored, and a nucleus of stocks can be supplied in very small quantities. The behaviour of seed from individual trees is also being investigated. Generally speaking, the Malling group C selections, the round-leaved thorny *P. communis* type, have proved the most promising stocks, and some of the most difficult to raise vegetatively.

Rootstocks for Plums.

Myrobolan B (Malling selection) has consistently proved to be an excellent stock for the production of large plum trees, and though it delays cropping slightly, it very soon catches up and passes trees on more dwarfing stocks. Moreover, this stock is readily raised from layers or by hardwood cuttings. Myrobolan B is excellent for damsons, and for all heavy-cropping varieties.

Brompton has also produced large healthy trees of all varieties and, in addition, has proved excellent for peaches. It is rather more difficult to raise than Myrobolan B, behaving rather similarly to Common Mussel in this respect.

Common Mussel has been disappointing. The trees on this stock have lost vigour quite early in life, and the fruit has not maintained size. In the nursery Common Mussel is not a favourite owing to its inclination to "spiny" growth, and its tendency to dry out during the budding season. Many plum varieties show leaf-scorch symptoms on certain soils upon this stock. Peaches grow quite satisfactorily on Common Mussel.

Common Plum has been shown to be a good stock for Victoria, producing medium-sized trees with early and heavy crops, and showing a high percentage of natural recovery from Silver Leaf. This stock is unsuitable for damsons, for Czar, and for certain other varieties of plum.

Marianna has, against all tradition, behaved exceptionally well in producing medium to vigorous trees which have carried the heaviest crops and, at the same time, the fruit size has been maintained. Marianna is not suitable for Czar or for peaches. It should be a great attraction to the tree raiser on account of its ready rooting from hardwood cuttings.

Pershore is an excellent stock for heavy-cropping trees of smaller size, and is compatible with all varieties so far tried upon it. Unfortunately, at present, the stock is so difficult to raise that it must be regarded as too costly for general use.

Brussels is one of the most widely distributed vegetative stocks in Europe. In the experiments at East Malling as in those at Long Ashton, Brussels has proved a most undesirable rootstock for the scion varieties used in the trials. At both centres yields have been low, at East Malling trees on Brussels have suckered freely, and the stock has shown incompatibility with certain scion varieties. In view of these results, growers are recommended to make sure that the trees they plant are not on Brussels rootstock.

St. Julien and Damas Seedlings. These plum stocks have been widely circulated on the Continent, but in our experiments stocks raised vegetatively from typical specimen seedlings of St. Julien and Damas have shown startling differences in the compatibility, growth and cropping of the trees worked on them. In view of this it would seem that St. Julien and Damas stocks, when raised indiscriminately from seed, cannot be expected to produce uniform trees, and for this reason they should be avoided.

Suckers of Local Varieties grown on their Own Roots.

The use of plum rootstocks of local origin, such as Pershore and Blaisdon Red, doubtless arose in the first place owing to the shortage of satisfactory plum stocks. Some of these local varieties have been included in plum stock trials at East Malling, but with the exception of Pershore, no stock of outstanding merit has yet been revealed.

In conclusion it should be emphasized that the recommendations given in this article are concerned with such rootstocks as are at present available to the Nursery trade. A large number of new rootstocks are now under trial here, apple rootstocks immune from woolly aphis, apple rootstocks raised by crossing various Malling stocks, and pear, plum and cherry stocks from many different sources. As a result of these trials it is hoped that within the next twenty years, rootstocks may be found with combinations of characters superior to any which have yet been produced.

SUMMARY.

A note on the available rootstocks for apples, pears and plums which from their performance at East Malling Research Station, and in various other experimental plantings in the South-eastern area, are considered suitable for most of the purposes required by commercial fruitgrowers in this country at the present time.

VARIETIES OF CHERRIES*

By N. H. GRUBB

A COLLECTION of cherry varieties was begun at East Malling in 1920; it has grown rapidly and is still being extended. However, it is by no means complete; a few English varieties and a considerable number of Continental sorts have not yet been obtained, unless they are already present under other names. Up to the present varieties have been received under 186 names (excluding ornamental sorts). In a few cases the buds or grafts failed to grow; and a number of names, such as St. Margaret's and Noble, are known to be synonyms. In other cases, however, there are two or more varieties under one name. Fully one-third of the varieties have not yet fruited at East Malling; until they do, it will not be possible to state the actual number of distinct varieties. It is probable, however, that the number is already above 150.

Varieties of cherries appear to be less well known and more confused than those of plums, apples and pears. This is perhaps only natural, since the wood, bud and leaf characteristics of cherry varieties are much less clear cut and distinctive than those of apples and pears, or even, perhaps, plums. But the confusion in nomenclature extends further than might have been expected. Of the varieties which have already fruited at East Malling, three received as black varieties proved to be white, and two received as white are actually black. At least two sweet cherries have been received under the names of acid varieties; and it is probable that one or two of those received as sweet cherries will turn out to be Duke or acid varieties.

When it is added that in several cases it has not yet been possible to determine, even from the fruit, whether varieties received under two names are really distinct or not, it will be seen that there is ample scope for work amongst cherry varieties.

Almost all the cherries grown for their fruit belong to two botanical species, the Sweet or Bird Cherry, Mazzard, Gean or Gaskin, *Prunus Avium*, and the acid cherry, *P. Cerasus*; there is also a large group of hybrids between these two species, usually called "Dukes". Of the very large number of known species of cherry, a few others bear edible fruit, and one or two are actually cultivated for their fruit, notably the Chinese Fruiting Cherry, *P. pseudo-cerasus*. Many varieties are grown for ornament, chiefly for their blossom; of these only two or three belong to the same two species as our fruiting cherries. The remainder are almost all Eastern, of Japanese or Chinese origin.

Both the sweet cherry and the acid cherry are believed to be natives of the British Isles, and occur in the wild state; the former is common in most districts, and varies within wide limits; the latter is much less frequent, and its variation is less well known. A third species, said to be a native of the shores of the Mediterranean, has been widely used as a rootstock for fruiting cherries; this is the St. Lucie Cherry, *P. mahaleb*.

Cherries are commercially grown for their fruit in many counties of England, and to a small extent in favoured districts of Wales and Scotland. Certain well-known varieties are widespread, and may be found in any county where cherries are much

* Reprinted from the Herefordshire County Council Agricultural Quarterly Journal, Vol. IV, No. 3. September, 1936. 119-23.

grown. It has been found, in addition, that each county which has any considerable acreage of cherries possesses its own local varieties ; these appear usually to be distinct from those of other counties. Local varieties, not so far identified with any found elsewhere, have been discovered in Berkshire, Buckinghamshire, Cornwall, Devonshire, Gloucestershire, Herefordshire, Hertfordshire, Kent and Worcestershire. Whilst it is possible that some varieties now regarded as distinct will prove to be identical, it is also probable that a complete survey of English cherry orchards would extend this list. The writer has seen good cherry orchards in Monmouthshire, but has not yet had an opportunity of enquiring about varieties.

One local variety, the Herefordshire " Ironsides ", has recently been identified with the variety grown in Kent as " Ohio Beauty ", a name used in its country of origin for a much earlier ripening cherry.

How is one to judge which of these many varieties will be most useful in a commercial cherry orchard ? The chief requirements are clearly a healthy long lived tree, which will bear regular crops of fruit readily saleable at a good price in the markets. Few varieties combine these requirements in a high degree ; and a variety which is excellent in one district may be poor in another.

Let us consider first the question of tree health. At East Malling the most serious cherry disease so far has been " bacterial die-back ", a " canker " which causes the death of branches and frequently of whole trees. It is probably the most frequent cause of the trouble known as " gummosis ". It has become clear that varieties differ very widely in their susceptibility to this disease, and that local conditions greatly affect its virulence. Of the varieties which have been grown at East Malling for ten years or more, perhaps one-third have usually been free from serious injury. A smaller number, perhaps one-sixth, have proved so susceptible that it has never yet been possible to grow a tree to fruiting age. The remaining half are moderately susceptible ; whilst whole trees are sometimes lost, it is usually possible with care to keep them growing.

Since this disease appears at present to be more serious at East Malling than in some of the chief cherry districts of England, it is not proposed to say very much about it here. Control measures (other than drastic surgery) at present under trial are spraying with Bordeaux mixture, and " frame-working " susceptible varieties on resistant stems.

Other diseases which sometimes affect cherry trees seriously are brown rot and cherry leaf-scorch. Both are caused by fungi ; and here again varietal susceptibility is an important factor. Two of the most regular cropping cherries we have, Governor Wood and Early Amber, are in some districts too susceptible to both these diseases to be satisfactory. And the most widely grown acid cherry, Morello, is so susceptible to the " blossom wilt " form of brown rot that it is by no means easy to grow. Control measures, chiefly spraying with tar oil and fungicides, give considerable hope of success in recent trials.

A good many varieties are still generally free from all these diseases. Of widely grown sorts, probably Early Rivers, Early Lyons, Knight's Early Black, Noir de Guben, Black Eagle, Waterloo, Caroon, Roundel, and Turkey Heart amongst blacks, and Frogmore and Amber Heart (syn. Kent Bigarreau) amongst whites, are generally healthy.

In cropping, many varieties are widely recognized as generally reliable, whilst others, like Elton Heart, are more often uncertain. Governor Wood and Early Amber have already been mentioned as particularly good ; in this respect few others can approach them, though one or two local varieties and perhaps Frogmore may do so. But for practical purposes Early Rivers, Noir de Guben, Waterloo, Roundel, Turkey Heart, Frogmore, Amber Heart and Napoleon are all good enough in most districts.

In regard to market quality of fruit also the present writer's experience is very limited. Most of the varieties listed above as generally healthy appear to be satisfactory. In Kent the chief varieties planted at present seem to be Early Rivers, Noir de Guben, Bigarreau Gaucher, Roundel, and Amber Heart, with Turkey Heart where canning fruit is required. Growers are no longer planting Napoleon so much as formerly, owing partly to its rather short life, and partly to the cracking of the fruit in a wet picking season.

Finally, a word about fruit quality may be useful. In the writer's opinion the best quality cherries for dessert are a local Kent variety, Nutberry Black (early midseason), a Herefordshire variety, Strawberry Amber, and a Duke, Belle de Choisy (midseason), followed at a distance by Elton Heart and Waterloo. For the garden these can hardly be surpassed ; Nutberry Black and Waterloo are also fairly good market varieties.

Summary.

This article gives preliminary results of the work on cherry varieties begun at East Malling in 1920. The number of distinct varieties in the East Malling collection is estimated at over 150, allowance being made for some confusion in nomenclature, of which instances are given.

Local varieties, apparently distinct from those grown elsewhere, have been found in every county where cherries are widely grown.

The chief requirements for a good commercial variety are discussed, and special attention paid to those varieties which have proved at East Malling to be most resistant to various diseases.

The article concludes with a few words about cropping and fruit quality.

NOTES ON ONE SEASON'S EXPERIENCE WITH COLD STORING PLUMS

By A. C. PAINTER

Introductory.

Experiments on the cold storage of plums already carried out by the Department of Scientific and Industrial Research have resulted in much valuable information becoming available to the grower. It is thought that a brief account of some experience gained here, when attempting to put into commercial practice some of the recommendations made, may prove of interest.

In view of the very large plum crop in 1936, and the low prices ruling on the market, a considerable quantity of plums—some 21 tons in all (mainly Victorias)—were placed in cold store, and held over until the market became less glutted.

The plums were graded and stored in the ordinary commercial way. When brought out for marketing, the amount of wastage was recorded, and notes were made on the condition of the fruit. It should be emphasized that the figures are not the results of closely controlled experiments. They are, however, sufficiently accurate to serve as a reliable guide.

No attempt was made to store any variety earlier in season than Victoria, since no advantage appears to be gained, unless the fruit can be held until the bulk of the Victorias is off the market.

Pre-Storage Treatment of Fruit.

As soon as it was decided that the time for storing had arrived the fruit was picked closer than one would do for ordinary marketing, in an endeavour to get it before it had begun to soften. Fruit in this firm condition will store better than more mature fruit. Owing, however, to the size of the crop and the rapidity with which the fruit ripened, it was not possible to get any very large proportion in the optimum condition for storing.

In the packing shed the plums were gone through, and where possible graded for size. The firmer undamaged fruit was transferred to trays normally used for gas storing apples. These trays held about 30 lb. of fruit and were lined with paper. The plums were put in the trays three to four deep, no attempt being made to fill them, and the trays placed in store as soon as practicable.

Storage Conditions.

The fruit was stored in one of the gas storage chambers temporarily used as an ordinary cold store. Small sliding panels in the walls made it possible for the chambers on either side to be used as pre-cooling rooms (see below).

Endeavour was made to keep the fruit at 34° F., but owing to the frequent opening of the doors for loading and unloading, it was found difficult to maintain this temperature and the average was nearer 35° to 37° F. Between 22nd and 26th September a choked strainer caused the temperature to rise to between 38° and 42° F., which undoubtedly had a detrimental effect on the storage life of the fruit especially where it was approaching maturity. This should be borne in mind when examining the figures for wastage.

Further, between 5th and 9th October, owing to a start being made with loading Bramleys into one of the adjoining chambers, it was not possible to maintain a lower temperature than 40° F. By then, however, there were not many plums left in store.

PRE-COOLING.

The following procedure was adopted when unloading. The temperature of one of the chambers adjoining that in which the fruit was stored was brought down to as near 40° F. as possible. Fruit intended for market was then transferred to it through the sliding panel, and the temperature allowed to rise slowly. The next morning the fruit was taken out and packed for market, and the temperature of the store again brought down to receive the next consignment. By this means it was found possible to avoid much of the sweating, or condensation of moisture, that occurs when fruit is brought straight out into a warm atmosphere.

VICTORIAS.

Fruit stored was picked between 26th August and 4th September and marketed between 10th and 25th September, the period of storage varying from thirteen to twenty-five days.

TABLE I.

VICTORIAS.

Lot No.	Dates Picked. P. Stored. S.	Date Marketed.	Interval between picking and marketing. Days.	Wastage% (including rots, over-ripe and damaged fruit).	Condition when stored.	Remarks.
1	P. 31st Aug. S. 31st ,,	16th Sept.	16	2·5%		
2	P. 31st Aug. S. 1st Sept.	16th Sept.	16	2·7%		
3	P. 1st Sept. S. 1st ,,	18th Sept.	17	4·6%		Marketed before rise in store temperature.
4	P. 1st Sept. S. 1st ,,	22nd Sept.	21	7·5%		
5	P. 1st Sept. S. 2nd ,,	22nd Sept.	21	8·1%	Mainly firm with a fair amount of colour.	
6	P. 2nd Sept. S. 2nd ,,	23rd Sept.	21	8·7%	Maturity increasing somewhat with each successive picking.	
7	P. 3rd Sept. S. 3rd ,,	23rd Sept.	20	10·8%		Marketed after rise in store temperature. Note rapid increase in wastage.
8	P. 3rd Sept. S. 3rd ,,	24th Sept.	21	16·2%		
9	P. 3rd Sept. S. 3rd ,,	25th Sept.	22	18·7%		
10	P. 3rd and 4th Sept. S. 4th and 5th Sept.	25th Sept.	21-22	33·0%		

Trees were picked over several times, only fruit in fairly firm condition being stored. The later pickings, however, were undoubtedly somewhat more mature than the earlier ones.

Some examples (Table I) taken from the storage records of fruit from one plot are typical of what took place.

The main point of interest in connection with these figures is the comparatively small amount of wastage in fruit marketed before 23rd September and the very rapid increase that occurred after the rise in store temperature. The fruit was then approaching maturity.

Again comparing lots 1 and 2 and lots 4 and 5 it should be noted that where there was delay in storing, wastage tended to be greater than when no delay took place.

It was observed that the flesh of Victorias that became over-ripe in store did not turn brown, but became soft, transparent and gelatinous.

Readers may here be referred to an article on the Cold Storage of Victoria Plums by W. H. Smith of Ditton Laboratory, which appeared in the Fruit-Grower of 4th February, 1937, page 161, and which deals with some of these points.

Giant Prune.

Picked between 8th and 14th September and marketed between 28th and 29th September, the period of storage varying from fourteen to twenty-one days.

Table II.

Giant Prune.

Lot No.	Dates Picked. P. Stored. S.	Date Marketed.	Interval between picking and marketing. Days.	Wastage % (including rots, over-ripe and damaged fruit).	Condition when stored.	Condition when marketed.
1	P. 8th Sept. S. 9th ,,	29th Sept.	21	4·5%	Very firm. Colouring up but large area of yellow background showing.	Still quite firm with considerable amount of yellow showing.
2	P. 9th Sept. S. 9th ,,	29th Sept.	21	3·7%	Ditto.	Ditto.
3	P. 9th Sept. S. 10th ,,	29th Sept.	21	5·0%	Ditto.	Ditto.
4	P. 11th Sept. S. 12th ,,	29th Sept.	18	8·2%	Ditto, but rather more coloured than lots 1 to 3.	Ditto.
5	P. 11th Sept. S. 12th ,,	28th Sept.	17	14·2%	Firm but well coloured and more mature than lot 4.	If anything a little on ripe side.
6	P. 14th Sept. S. 14th ,,	28th Sept.	14	14·3%	Firm, but well coloured and more mature than earlier lots.	If anything a little on ripe side. There was a greater proportion of ripe but marketable fruit in No. 7 than in No. 6, viz. 6% against 2%.
7	P. 14th Sept. S. 15th ,,	29th Sept.	15	14·5%	Ditto.	

Note.—The fruit from this plot appeared to be of very good keeping quality.

Fruit from the early pickings was in very firm condition, but that picked later was distinctly more mature. Table II gives complete storage records for the entire crop of Giant Prune from one of the plots where some clear cut comparisons are possible since the trees from which the fruit came were all of the same age and the fruit from each tree stripped at one picking. Picking, moreover, extended over a period of days, thus enabling a comparison to be made between fruit stored at different stages of maturity.

Comparing lots 1 to 3 with lots 4 to 7 it will be noticed that there was considerably less wastage in the earlier picked fruit, though it was stored for a longer period than that picked later on. Actually, the wastage was progressively greater the longer picking was delayed.

Again comparing lots 2 and 3, both picked on the same day, wastage was greater in No. 3 where storage was delayed, and the same tendency is seen in the case of lots 6 and 7 though the difference perhaps is not so marked. There was, however, more ripe but marketable fruit in No. 7 than in No. 6.

Lots 4 and 5 were from one picking and graded according to maturity, No. 4 consisting of the less mature and No. 5 of the more mature fruit. Again, wastage was considerably greater in the more mature fruit.

Pond's Seedling.

Picked between 4th and 11th September whilst still firm and with varying amount of colour. Marketed between 28th and 30th September, the period of storage ranging from eighteen to twenty-six days.

This variety did not store well in whatever stage it was picked and considerable wastage was experienced. This wastage, which varied from 15% to 30%, was mainly due to internal browning of the flesh, the fruit being quite sound to outward appearance. It is possible that it was stored too long and that a shorter period of storage might have given better results.

Cambridge Gage.

Picked on 26th and 27th August and marketed 24th September after a period of twenty-eight to twenty-nine days.

Only a small quantity of fruit of this variety was stored. Though in good dessert condition when marketed, it had probably been kept a little too long, wastage at 14 per cent. being somewhat high. The fruit showed a tendency to shrivel.

Warwickshire Drooper.

Picked between 11th and 15th September and marketed on 8th October after a period of storage varying from twenty-three to twenty-seven days.

Considering that the fruit was subjected to two periods of high temperature (p. 288) it stored well, good firm fruit picked and stored the same day only having a wastage of 3·5%. As in the case of other varieties the highest wastage occurred where there was delay in storing and where the fruit was on the more mature side when picked.

This variety had a severe attack of Sooty Blotch, and fruit so affected shrivelled somewhat badly.

Cluster Damson.

Picked between 11th and 15th September and marketed between 2nd and 9th October, the period of storage varying from seventeen to twenty-five days. The fruit was quite firm but had passed the immature stage when picked.

These also were subjected to two spells of high temperatures. However, the condition of the fruit at time of marketing was such that it would have been possible to have stored it satisfactorily over a longer period had not the stores been required for apples. Wastage varied from 3% to 6%, except with three lots of fruit where it was between 10% and 12%. In each of these cases, however, there had been an interval between picking and storing. The increase in wastage that follows delay in storing is well brought out in Table III. All this fruit was picked on one day, but different lots accorded different treatment subsequently. At the end of three weeks, wastage was twice as much where a delay of one day occurred between picking and storing (lots 4 and 5) and still more where there was an interval of two days (lot 6) when compared with fruit stored the same day as picked (lots 1 and 2).

There was a certain amount of shrivelling with this variety, especially where affected with Sooty Blotch.

TABLE III.

CLUSTER DAMSON.

Lot No.	Dates Picked. P. Stored. S.	Date Marketed.	Interval between picking and marketing. Days.	Wastage % (including rots, over-ripe, damaged and shrivelled fruit).	Condition when stored.
	(One day's picking from one plot.)				
1	P. 15th Sept. S. 15th ,,	7th Oct.	22	5·7%	
2	P. 15th Sept. S. 15th ,,	8th Oct.	23	4·5%	
3	P. 15th Sept. S. 16th ,,	2nd Oct.	17	3·2%	Firm but fully coloured.
4	P. 15th Sept. S. 16th ,,	7th Oct.	22	10·3%	
5	P. 15th Sept. S. 16th ,,	9th Oct.	24	10·0%	
6	P. 15th Sept. S. 17th ,,	6th Oct.	21	11·7%	

THE ECONOMIC ASPECT.

It is not possible to give a hard and fast figure that would cover the cost of cold storage in every case, as it will naturally depend on such factors as the cost of electricity or other power, the size of the store, the quantity of fruit stored, and any depreciation, etc., that it may be thought necessary to provide for.

In the present case, where gas storage chambers were used and some 20 tons of fruit stored, it is estimated that the additional cost involved was under 4d. a 12 lb. chip, made up as follows :

Power. Electric current over a period of six weeks .. .. $\frac{3}{4}$d.

Loading and Unloading of Store. At the most .. .. $\frac{1}{2}$d.

Extra Handling in the way of sorting, etc. This varied from under 1d. a 12 lb. chip for good sized plums to rather over $1\frac{3}{4}$d. on occasions for damsons. On an average say .. .. $1\frac{1}{4}$d.

Charges for Depreciation, etc. Share of annual charges on account of maintenance, depreciation, interest on capital, etc., based on six weeks' running .. .. $1\frac{1}{4}$d.

Most stores are erected primarily for the storing of apples, but should the store be used mainly for plums, the charge under this heading will be considerably higher.

The market price for the plums from cold store showed an increase of anything from 6d. to 1s. 6d., and occasionally as much as 3s., per 12 lb. chip over prices ruling at the time when they would normally have been marketed. This often represented a 75% to 100% increase on the earlier net return, and was thus sufficient to cover all but abnormal wastage and to make storage well worth while.

Some Observations and Recommendations.

The main points of interest to be noted in the foregoing are :

(1) Maturity at time of picking had a considerable effect on the subsequent keeping of the fruit. The more mature the fruit the shorter its storage life. (*Note.*—No fruit was picked in a definitely immature stage. Endeavour was made to gather it whilst still quite firm but definitely commencing to colour. In the light of experiments carried out by the Department of Scientific and Industrial Research, the recommendation can be made that most ordinary plums are best picked in this condition, and then stored at a temperature of about 34° F. Damsons and certain other plums, however, can be picked in a more immature state and will keep perfectly satisfactorily.)

(2) Fruit stored the same day as picked kept better than when an interval of a day or more was allowed to elapse between picking and storing. The longer the fruit was stored the greater did the difference tend to become. The inference is obvious, the sooner fruit can be placed in store after picking the better. A few hours in a high temperature will considerably lessen its storage life.

(3) Rapid deterioration occurred in fruit nearing the end of its storage life when subjected to a higher temperature. This emphasizes the importance of not allowing fruit to become too ripe before it is marketed, as otherwise it may break down before the salesman or retailer can dispose of it.

(4) Certain varieties such as damsons and greengage, and to a lesser extent Warwickshire Drooper, showed a tendency to shrivel whilst in store. In addition, in the case of Warwickshire Drooper, extensive shrivelling was caused by Sooty Blotch. On the other hand little or no shrivelling was noticed with such varieties as Victoria, Giant Prune and Pond's Seedling.

Those contemplating storing plums would be well advised to refer to the Department of Scientific and Industrial Research Food Investigation Leaflet No. 1, *The Cold Storage of English Plums*,* by Dr. Franklin Kidd of the Low Temperature Station, Cambridge, and Dr. Cyril West of Ditton Laboratory, East Malling, Kent, to whom enquiries on the subject can also be made.

An article on fungi which cause wastage in cold stored plums appears on p. 198.

Acknowledgment.

The writer is much indebted to Dr. Cyril West of Ditton Laboratory for reading through these notes and for much valuable help and advice during the period of storage.

* Obtainable gratis on application to the Secretary, Department of Scientific and Industrial Research, 16 Old Queen Street, Westminster, London, S.W.1.

Summary.

1. An account is given of a season's work on cold storing plums commercially.
2. Maturity at time of picking was found to have a considerable influence on the storage life of the fruit. Fruit picked whilst firm and beginning to colour kept better than fruit picked when more mature.
3. Delay in putting the fruit into store after picking definitely lessened its storage life.
4. Some approximate figures of the cost of storage are given.
5. Some recommendations are made in light of the above.

References.

(1) Kidd, F. and West, C. "The Cold Storage of English Plums." Department of Scientific and Industrial Research Food Investigation Leaflet No. 1.

(2) Smith, W. H. "Cold Storage of Victoria Plums—Experiments at Ditton Laboratory." Fruit-Grower, 4th February, 1937, 161.

MYCOLOGY AND BACTERIOLOGY

SOOTY BLOTCH OF APPLES AND PLUMS*

By H. WORMALD

As a result of the cold, damp summer, the disease known as Sooty Blotch, caused by the fungus *Gloeodes pomigena*, has been very prevalent this year, and many inquiries concerning it have been received at East Malling. Even some of the fruit exhibited at shows has borne this blemish. During years when the rainfall and sunshine are round about the average there is, as a rule, not enough Sooty Blotch for the grower to give it any special attention, and in hot, dry seasons it is almost or quite unnoticed. For this reason no special precautions are taken by British fruit growers to prevent it, although the ordinary routine treatment against Apple Scab probably tends to keep the disease in check during a normal season, especially when a late spray or dust is applied.

Sooty Blotch would appear to be more important in America than in this country, and it has been investigated by a number of workers in the United States, where routine spraying with Bordeaux mixture or lime-sulphur, as used against Scab, is said to be effective against Sooty Blotch also.

The more immediate need of the British grower this year is to know how to treat the gathered crop when it is seriously disfigured by the Blotch. The treatment recommended in America is a bleaching method, using the so-called Javelle water which is prepared by heating together, in water, bicarbonate of soda and chloride of lime. A simpler method, using chloride of lime alone, has been evolved by an experimenter in South Africa. Both methods have been tried at East Malling and both have been found to cause a considerable improvement in the appearance of the treated fruit. As there is little to choose between the two treatments with regard to the final results, the simpler method is given here.

Chloride of lime (bleaching powder) is added to water at the rate of $\frac{1}{2}$ lb. to the gallon. The mixture is well stirred and then allowed to settle. It may, if found to be a convenience, be left overnight to settle, for use the next day. The clear liquid is decanted or siphoned off and the sediment discarded. The fruit is immersed in this liquid for one minute. This bleaches the fungus on the blotches and the apples are then washed in clean water and allowed to dry. The method has been tried at East Malling, but only on a small scale, and the most convenient way of dealing with large quantities of fruit has not been determined. A method suggested is to load the fruit into shallow trays, in which it can be immersed in the liquid, taken out, exposed to the air, washed, and allowed to dry before it is removed from the trays.

The fungus penetrates only a little distance into the skin of the fruit and much of the blotch can be removed by wiping the fruit with a damp cloth ; this involves the handling of each individual fruit, but it may be found practicable unless large quantities of fruit are to be treated.

* Reprinted from the Journal of the Ministry of Agriculture, Vol. XLIII, No. 10 (January, 1937), pp. 923-5, by permission of the Controller of H.M. Stationery Office.

Sooty Blotch occurs also on plums, some varieties of which may be so severely blotched as to be most unsightly. This is especially true of green- and yellow-skinned plums such as Warwickshire Drooper and Pershore Egg. Red and purple plums, however, may become infected also, although the blotching is less conspicuous than on the fruit with paler skins. The bleaching treatment recommended above has been used at East Malling on plums and found to be successful.

Summary.

Sooty Blotch of apples and plums was very prevalent in 1936 as a result of the cold, wet summer.

A chloride of lime treatment is recommended for cleaning fruit showing this disease.

BACTERIAL CANKER IN PLUM AND CHERRY TREES*

By H. WORMALD

FRUITGROWERS in many parts of the country have experienced great losses from what is commonly known as "Die-back" in plum and cherry trees. In the last season particularly, losses were exceptionally severe and it seems an opportune time to review the situation, to pool our information, and to consider future investigations.

More intensive observations in the plantations seem desirable in order to ascertain what are the conditions under which this diseases is so destructive, and to devise more certain means for controlling it. We should, therefore, like to get in touch with those growers who have suffered losses from this disease.

The disease must have been known for 40 years or more, for it is mentioned in the reports of the Woburn Fruit Farm towards the end of last century. It is comparatively recently, however, that any exact information has been obtained as to the cause of this trouble although various hypotheses to explain it have been put forward from time to time. Thus certain fungi found on diseased trees have been suspected as the cause but no real evidence has been forthcoming that any of these fungi could produce the destruction so evident in the plantation. Again it has been suggested that unfavourable soil conditions are the chief cause, that water-logging, for instance, causes die-back. There can be no question that if trees are grown in soil totally unsuited for their well-being they cannot thrive and will tend to die prematurely. But this cannot explain the great majority of cases where trees have died suddenly in what would appear to be soil particularly suitable for growing plums or cherries. Nor does it explain those cases where a tree completely withers in less than a year while trees within a few yards continue to thrive and make luxuriant growth.

About twelve years ago trees on our trial plots of plums were being decimated by a disease, at that time called die-back, although many of the trees died completely in a single season, and there was no evidence of dying back from the tips downwards as suggested by the term "die-back".

This offered a good opportunity for a closer investigation of the disease in an endeavour to obtain some exact information as to its cause and its control. Trees that were seen to be dead or dying during the summer were taken up for examination. It was found that (1) the roots were well developed and healthy, showing that the soil conditions at any rate were not detrimental to root growth, (2) there was a sunken, cankered area with brown bark on each stem or crotch suggesting stem infection by some parasite, (3) on these cankers there were sometimes various fungi, but a more careful microscopic examination showed that towards the upper and lower limits of the cankers (where the diseased parts bordered on the healthy) there were crowds of bacteria, and the fungal threads were to be found only in the more central parts of the cankers. This suggested that the bacteria might be the cause and that the fungi were merely saprophytes living on the parts already killed by the bacteria. This hypothesis was put to the test.

* Paper read at a Conference on Bacterial Die-Back in Plums and Cherries, held at the East Malling Research Station, 10th March, 1937.

The first step was to isolate the bacteria in pure culture. The first attempts to do this failed—they refused to grow ; the reason of this was not obvious at the time, but it was suspected that they died out during the summer and that if they were the cause of the cankers they must have been alive earlier in the season when the cankers were developing. This proved to be the explanation, for trees the next year were examined in the spring when the symptoms of disease first showed. The diseased bark was then found to contain numerous living bacteria and an organism was isolated from a number of trees. In the autumn the parasitism of this organism was tested by putting it back into healthy trees to see if it would reproduce the disease.

Without going into details it may be said that on a plot of twenty young plum trees, ten had the bacteria put into them (they were inoculated as we say) by making a cut in the bark and inserting a drop of water containing the bacteria ; the other ten were control trees for comparison—they were cut in the same way but sterile water only inserted.

During the following spring and summer all the inoculated trees showed the symptoms typical of the disease in the plantation, and cankers appeared on the stems ; the cankers girdled the stems and in every case the upper part of each tree died. On the other hand all the control trees remained healthy and no cankers developed on them.

We had thus got definite evidence that the disease was caused by a bacterium and the next step was to find out something about its habits so that we might investigate means for preventing its ravages in the plantation. In order to ascertain at what time of the year infection might take place other trees were inoculated at monthly intervals throughout the year. It was found that the largest cankers, resulting in girdling and death, developed when the stems were inoculated about leaf-fall (October or November) whereas inoculations made during the summer months produced no cankers at all.

Observations also showed that cankers which resulted from infection in autumn and winter ceased to increase in size during the summer, and moreover that the bacteria in the cankers died out in summer. A further step, therefore, was to find out how the organism survived the summer in order to produce further infection in the autumn.

An examination of trees in the plantation showed that trees otherwise quite healthy —not cankered or dying back—had spots on their leaves, these spots eventually falling out and leaving " shot holes ". On microscopic examination such spots were seen to be swarming with bacteria and the organism when isolated proved to be the same as the one found in the stem cankers ; when this leaf organism was inoculated into plum stems it produced the typical cankers. It was clear then that this disease was caused by bacteria which spend the winter in stems and branches, producing cankers, and the summer in the leaves, causing leaf spots. This particular form of Die-back we now distinguish as Bacterial Canker, and it is undoubtedly one of the chief causes of the loss in plantations of plums and cherries.

The symptoms of Bacterial Canker in plum trees are these. On established trees in the plantation the leaves in spring are yellowish, narrow and curled ; the shoots are usually stunted, the terminal ones particularly remaining short ; cankers appear on stems or branches, becoming more and more conspicuous throughout the summer and when the cankers girdle the stems the trees die.

On maiden trees in the nursery the symptoms are similar but more pronounced, so that some of the trees make no move at all in spring ; buds on a portion of the stem do not swell ; this area will prove to be cankered and if girdled the parts above will die some time during summer.

On cherry trees the symptoms are very similar to those on plum. Stem and branch cankers occur, but the branch cankers are of more frequent occurrence and gumming is

more profuse. The yellowing and curling of the leaves is followed by the withering of the whole tree or affected branch. Bud and spur infections are frequently found on cherry trees.

Last season (1936), with its rather cold and wet summer, it was found that some cherry cankers remained active, with living bacteria in them, well into the summer, late July and early August.

A tree showing leaf spots is not necessarily cankered, and as a matter of fact the spots are usually most conspicuous on trees which are not cankered. As already mentioned, however, the canker organism spends the summer in these spots and they must be looked upon as a danger signal. The spotting itself is, as a rule, not very destructive, though when severe it may cause the leaves to wither and may result in premature defoliation. Not only the leaves but also the young shoots may become infected in spring and summer, and when the leading shoots are attacked, as they are sometimes on certain varieties of cherries, the result may be rather serious. The same bacteria also attacks the fruit, but this infection of fruit is not in itself serious.

I have referred to *the* organism which causes these diseases. As a matter of fact there are two species of bacteria concerned, as distinguished by our cultural methods. Sometimes one of these is found in the cankers and leaf spots and sometimes the other. One of them appears to be more widely distributed in the British Isles and is generally more destructive than the other, particularly on plums, but for practical purposes they may be considered as one organism.

It may be asked why we spend so much time in determining the cause of these diseases and identifying the parasites. This particular disease shows the importance of this side of the investigation. It gives us a more exact basis for devising methods of control and it also enables us to determine what particular host plants harbour the parasite. A study of the organism has shown clearly that the disease is not directly due to unsuitable soil conditions. Inoculation experiments and field observation have proved that of trees growing side by side on the same soil one may be killed, when infected, while next to it a tree, free from the organism, thrives.

Again when it was assumed that fungi were the cause all one could recommend was the destruction of affected trees when the symptoms of disease became apparent in the summer. Now that we know that bacteria are the cause and that they effect their damage in the winter and early spring and die out in summer, the removal and destruction of diseased trees in summer is valueless as a preventive, for the actual cause of the trouble has by that time died out.

The exact identification of the cause of the disease also enables us to determine what host plants harbour the parasite and so serve as sources of infection for others.

We have found out in this way that Bacterial Canker or Leaf Spot or both, may occur not only on plums and sweet cherries but also on Morellos and the Cherry Plum (Myrobolan) as well as on certain ornamental bushes as Almond and the Purple Leaved Plum (*Prunus Pissardii*). There is also the suspicion that ornamental flowering shrubs such as Lilac and Forsythia, which are subject to bacterial blight, are hosts of one of the organisms which attack plums and cherries.

Again recent work suggests that a bacterial blossom wilt and a fruit spot of pears are also caused by one of these Bacterial Canker organisms.

The ornamental plants mentioned are not likely to be a source of trouble in the plantation, but a watch must be kept in nurseries where ornamental trees and bushes and fruit trees may be grown in close proximity. The question of infection in the nursery is an important one. The nurseryman for his own reputation must ensure that he is not sending out infected trees.

CONTROL.

The primary object of this investigation is to solve the problem of how to control Bacterial Canker and prevent this destruction in plantations and orchards of plums and cherries.

How then does the information we have acquired enable us to do this ? It must be confessed that the problem has proved a difficult one and we cannot yet offer any infallible means of keeping the disease in check. However, certain lines of approach are suggested and these will now be considered.

(1) *Removal of affected trees.* When a tree is girdled by a canker there is no chance of its recovery, and it should be removed, but this should be done early in the spring when the symptoms of disease, as shown by the yellow foliage, are first noticed, and while the organism is still alive in the cankers.

(2) *Cutting out cankers.* Small cankers which do not girdle the stem or branch may be cut out, but again, if done at all, the operation should be carried out early in spring, and as a precaution the wound should be painted over with a disinfectant. If left until summer such cankers tend to become healed naturally, but in the meantime the bacteria in them may have been spread to the leaves by rain or insects.

(3) *Avoid injuries to stem and branches in autumn.* Infection of the stem takes place in autumn, probably about leaf-fall, and as infection takes place mostly through wounds, pruning, defeathering, or cutting back should be avoided about that time.

(4) *The use of resistant stems.* Some varieties of plums and cherries are more resistant than others, and it has been suggested that it might be advantageous to provide stems and frameworks of such varieties on which to work the more susceptible but more useful varieties. Experiments on these lines are being carried out.

(5) *Soil treatment.* The disease occurs on many types of soil, and at present we have no exact information that any one type of soil is better than another for the prevention of this disease. The question of soil treatment is under investigation, however.

It has been suggested that potash might tend to harden the tissues and so induce resistance. In field plots and sand cultures no evidence could be obtained that success could be obtained by applications of potash ; in one field trial of nursery trees there was actually most cankering on the plots which received dressings of potash.

Another suggestion was that applications of lime might produce resistance. In a field trial of young trees in nursery rows it was found, however, that, on the whole, cankers were larger on plots receiving lime than on unlimed plots.

In one manurial trial plum trees were grown in pots of sand to which were added various inorganic nutrient solutions. The trees were eventually inoculated with the Bacterial Canker organism and the resulting cankers measured. There was no great difference obtained by varying the proportion of nitrogen and potash from the " complete nutrient ", but with excess of phosphate (quadruple normal) the cankers were largest, while with " no phosphate " the cankers were very small. In view of these results it would be unwise, with our present knowledge, to apply heavy dressings of inorganic phosphatic manures in plantation subject to Bacterial Canker.

Spraying. Since the organism spends the summer in the leaves and infects the stems in autumn, attempts have been made to control the leaf spot phase by spraying the foliage, and stem infection by spraying in autumn, using Bordeaux mixture. The results up to the present have been inconsistent, but some degree of success has been obtained

in trials on this Station, and certain growers report a reduction in the incidence of disease following autumn spraying of the stems.

Investigations are proceeding in order to obtain further knowledge on these points. In the meantime growers can help by informing us as to the type of soil on which this disease does not occur or on which it is prevalent. We should also be pleased to receive any information regarding results obtained by spraying.

Summary.

The symptoms of Bacterial Canker in plum and cherry trees are (1) curled, yellowish, leaves in spring, (2) the appearance during summer of cankers on the affected stems or branches, (3) the final withering of trees or branches girdled by cankers.

The organism causing Bacterial Canker passes the summer on the foliage, causing leaf-spots. In autumn and winter it lives in the stems and branches and produces cankers, which show the following summer.

The control of this disease is being investigated along various lines, including spraying the foliage in summer, and the stems and branches in autumn, with Bordeaux mixture.

INSECTICIDES AND FUNGICIDES

THE CONTROL OF CODLING MOTH
A SUGGESTED SPRAY PROGRAMME

By W. STEER

THE following spray programme is based on recent experience of Codling Moth at East Malling.

A. WHERE SEVERE ATTACKS HABITUALLY OCCUR ON APPLES.

1. *Calyx Spray.* Apply the following at petal fall:

Lead arsenate paste	4 lb.
Lime-Sulphur* (for Scab and Red Spider)	1 gal.
Nicotine (for Sawfly)	8 oz.
Water	to 100 gal.

2. *First Cover Wash.* Late in June (say 23rd to 30th June). Repeat the calyx spray, but omit the nicotine.

3. *Second Cover Wash.* Mid-July (say 10th to 15th July). Repeat the first cover wash on very late varieties such as Edward VII. For other varieties substitute Derris (2 lb. per 100 gallons) for the lead arsenate.

B. FOR MODERATE OR SLIGHT ATTACKS ON APPLES.

The first cover wash (23rd to 30th June) of lime-sulphur and lead arsenate should prove sufficient.

C. FOR CODLING ON PEARS.

Put lead arsenate in the second post-blossom scab spray and make sure that the calyx cup is well filled with spray.

Early apple varieties (such as Emneth) should not be sprayed with lead arsenate in July, and it is unsafe to spray any but very late varieties as late as the middle of July.

SUMMARY.

Details are given of a spray programme for the control of Codling Moth on apples and pears, based on recent experience of this pest at East Malling Research Station.

* Omit lime-sulphur on sulphur-shy varieties (Lane's, Stirling, Beauty of Bath, Rival, Newton).